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Trybliographa rapae (Westw.) (Hymenoptera: Cynipidae), A Parasite of *Hylemya* spp. (Diptera: Anthomyiidae)[1]

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Observations on the biology of *Trybliographa rapae* (Westw.) were made as part of a general study, in Canada and Europe, of the biotic factors acting against the maggots of *Hylemya brassicae* (Bouché), *H. floralis* (Fall.) [*H. crucifera* Huck.], and *H. cilicrura* (Rond.) that attack cruciferous crops. During the study many thousands of host insects from both Canada and Europe were examined and large numbers of both hosts and parasites were reared in the laboratory.

Several workers, notably James (1928) and Moltschanova (1930), have already published data concerning this parasite but their observations were made from a small amount of material and from limited areas. Moreover, the findings of the present authors on several points are not in agreement with those of the authors mentioned.

According to Weld (1952), the genus *Trybliographa* Foerster (=*Cothonaspis* auct., *non* Hartig, =*Dimicrostrophis* Ashm., =*Dusmetiola* Tavares) belongs in the subfamily Eucoilinae.

All the cynipids reared from the collections were identified as *Trybliographa rapae* (Westw.). *Cothonaspis gillettei* Washb. (Washburn, 1907-08; Schoene, 1916; Gibson and Treherne, 1916) is therefore considered to be synonymous with *T. rapae*.

Distribution and Hosts

In the present work, *T. rapae* was found in all countries from which host insects were examined (Table I), except Japan.

Abundance and Economic Importance

The information obtained in this study consisted entirely of records of occurrence and data pertaining to the percentage of the population attacked and subsequently destroyed. The role of *T. rapae* in governing the abundance of the host insects and its economic significance, were not evaluated.

Attack by *T. rapae* in the samples examined varied from one to 45 per cent (Table II). The percentage of attack by *T. rapae* reported by other workers is as follows: Minnesota, 36.6 (Washburn, 1908); New York, 18.5 (Schoene, 1916); England, 25 (James, 1928); Holland, 2 (de Wilde, 1947). These data are all within the limits of those of the present authors.

Descriptions of Immature Stages

Egg

The egg of *T. rapae* is similar to that of other parasitic Cynipidae as described by Keilin and Pluvinel (1913), Huzimatu (1940), Jenni (1951), and others. When newly laid (Fig. 3) it is ovoid in shape, 0.5 mm. in length, and 0.16 mm. in diameter; the stalk, or pedicel, is approximately 0.35 mm. long. The ovarian

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TABLE I
Distribution and Hosts of *Trybliographa rapae*

	Hylemya brassicae (Bouché)	*H. cilicrura* (Rond.) [=*H. cana* Macq.] [=*H. fusiceps* (Zett.)]	*H. floralis* (Fall.) [*H. crucifera* Huck.]	*H. antiqua* (Mg.)	*H. planipalpus* (Stein.)
Switzerland	x*	x			
France	x	x			
Belgium	x	x			
Holland	x (1)**	x			
Germany	x (2)				
Denmark	x		x		
Norway	x		x	x	
Sweden	x (3)		x (3)		
Scotland	x		x		
England	x (4)	x			
Russia	(5)		(5)		
United States	(6)				
CANADA					
Newfoundland	x				
Prince Edward Island	x				
Nova Scotia	x				
New Brunswick	x				
Quebec	x				
Ontario	x	x		x (7)	
Manitoba		x	x	x	x
Saskatchewan			x		
British Columbia	x (8)	x		x (8)	x

*Authors' records.
**(1) de Wilde, 1947; (2) Dalla Torre and Kieffer, 1910; (3) Lunblad, 1933; (4) Smith, 1927; (5) Moltschanova, 1930; (6) Schoene, 1916; (7) Hammond, 1924; (8) Gibson and Treherne, 1916.

TABLE II
Percentages of *Hylemya* spp. from Europe and Canada yielding *T. rapae*, 1949–51.

Area	Year	Host	Percentage parasitism
EUROPE			
Switzerland	1949	*H. brassicae*	9.6
France	1950	*H. brassicae*	6.3
Belgium	1950	*H. brassicae*	21.6
Holland	1950	*H. brassicae*	9.8
Holland	1951	*H. brassicae*	15.1
Denmark	1951	*H. brassicae*	1.5
Denmark	1951	*H. floralis*	2.4
Norway	1950	*H. brassicae*	2.6
Norway	1951	*H. brassicae*	3.9
Norway	1951	*H. floralis*	20.8
Sweden	1950	*H. brassicae*	5.3
England	1950	*H. brassicae*	12.8
Scotland	1951	*H. brassicae*	6.7
Scotland	1951	*H. floralis*	6.2
CANADA			
Newfoundland	1951	*H. brassicae*	1.6
Prince Edward Island	1951	*H. brassicae*	1.3
New Brunswick	1951	*H. brassicae*	10.1
Nova Scotia	1951	*H. brassicae*	21.3
Quebec	1951	*H. brassicae*	5.4
Ontario	1951	*H. brassicae*	1.1
Manitoba	1951	*H. floralis*	1.1
Saskatchewan	1951	*H. cilicrura*	45.6
British Columbia	1951	*H. cilicrura*	2.5

egg (Fig. 1) is smaller, being 0.26 mm. in length and 0.09 mm. in width. The egg increases in size very rapidly after it is deposited; all eggs dissected out of hosts less than one hour after deposition were of the size and form shown in Fig. 3. What substance comprises the newly acquired bulk was not determined. The stalk, or pedicel, is tube-like in form and bears the micropyle (Fig. 2) at its tip, which is the anterior end. Succeeding stages in the development of the egg are shown in Figs. 4, 5, and 6.

First-stage Larva

The primary larva (Fig. 7) is subcylindrical in shape, with a distinct head. The thorax bears on each segment fleshy, leg-like appendages and there is a long caudal appendage. At eclosion the larva is 0.67 mm. long and the caudal appendage 0.24 mm. long. There are seven well-defined abdominal segments and it must be presumed that the caudal appendage is comprised of the other three segments. The anus opens dorsally behind the seventh abdominal segment. Ventrally on the head are two prominent projections, which may be sensory in nature. The mouth is borne on a projection in an antero-ventral position. According to James (1928), a small sclerite is distinguishable inside the mouth but there is no indication of mandibles. The present authors found small (0.015 mm. long and 0.006 mm. wide) but distinct and well-sclerotized mandibles (Fig. 8). These were found only under very high magnification and were probably not observed by previous workers because of the great difficulty in arranging mounted specimens in a position in which they can be observed. Huzimatu (1940) found mandibles in the primary larva of *Kleidotoma japonica* Huz.

Second-stage Larva

The second-stage larva is 2.3 mm. in length and 0.82 mm. in diameter when full-grown. It resembles the first-stage larva slightly, but is more nearly cylindrical. There are no thoracic appendages and the caudal appendage is much reduced. The oral opening is less ventrad and more cephalad in position and the mandibles (Fig. 9) are larger. The integument is thin and soft and there is no tracheal system or spiracles.

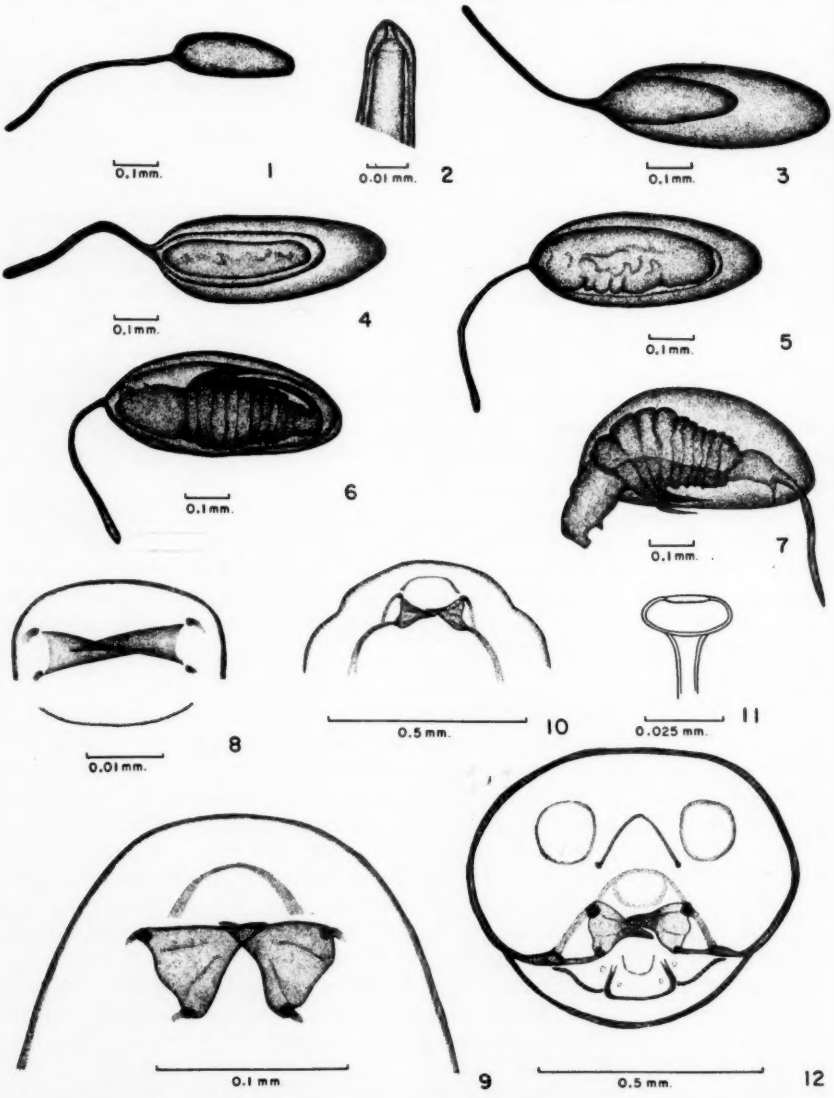
Third-stage Larva

The third-stage larva is 3.55 mm. in length and 1.08 mm. at its greatest diameter. It is subcylindrical in shape, being slightly flattened dorso-ventrally. It bears more resemblance to a typical internal hymenopterous larva than either of the former stages. There are three thoracic and ten abdominal segments. The oral opening is farther forward than in the second stage. The integument is thin and adapted to apneustic respiration. There is a spiracular system with lateral trunks connected by transverse tracheal bands in the prothoracic and tenth abdominal segments. A single pair of spiracles (Fig. 11) open between the first and second thoracic segments but undoubtedly belongs to the second thoracic segment. The spiracles have no closing apparatus.

None of the other workers making observations on *T. rapae* has observed this larval stage. This may be due to its relatively short duration. When puparia are dissected most of them yield second-stage larvae if the parasite has not left the host, or fourth-stage larvae if it has. The larva leaves the inside of the host and takes up an external feeding position in the third stage. It is therefore adapted both for apneustic and hemipneustic respiration.

The presence of but a single pair of spiracles in a hymenopterous larva is rare and has not been observed by the present authors in other species. Chrystal (1930) states that the third stage of *Ibalia leucospoides* Hochenw. possesses two

pairs of spiracles, one pair on each of the second and third thoracic segments. For *K. japonica*, Huzimatu (1940) reports that the penultimate stage bears three pairs of spiracles, one pair on each of the second and third thoracic segments and one pair on the first abdominal segment. Imms (1930) does not provide for this type in his classification of the types of respiratory systems of insects.



Figs. 1-12. *Trybliographa rapae* (Westw.). 1, Ovarian egg; 2, Tip of pedicel showing microphyle (diagramatic); 3, Egg, one hour old; 4, Egg, 24 hours old; 5, Egg, 48 hours old; 6, Egg, 72 hours old; 7, Newly hatched larva, 96 hours after oviposition; 8, Mandibles, first-instar larva; 9, Mandibles, second-instar larva; 10, Mandibles, third-instar larva; 11, Spiracle, third-instar larva (diagramatic); 12, Cephalic structures, fourth-instar larva.

Fourth-stage Larva

In contrast with James (1928) and Moltschanova (1930), four larval instars were found in *T. rapae* as indicated by the sclerotized parts of the head and the number and position of the spiracles. Huzimatu (1940) found five in *K. japonica* and Chrystal (1930) four in *I. leucospoides*. If a fifth occurs it is between the first and what has been described here as the second or between the second and what has been described here as the third.

The fourth larval stage of *T. rapae* varies considerably in size, depending on the size of the host in which it has developed. The observed lengths varied from 2.64 mm. to 4.4 mm. and the widths from 1.25 mm. to 1.98 mm. This variation depends on the host species and also the stage at which the attack takes place. This stage is a typical, grub-like hymenopterous larva and is adequately described by James (1928) except that it has nine pairs of spiracles rather than eight, one pair on each of the second and third thoracic segments and on each of the first seven abdominal segments. Huzimatu (1940) reports nine for the ultimate stage of *K. japonica* and Chrystal (1930) ten for that of *I. leucospoides*.

Hypermetamorphosis

Hypermetamorphosis occurs in the larvae of all the entomophagous Cynipidae that have been studied. Since Keilin and Pluvinel (1913) described the primary larva of *Eucoila keilini* Kieff., the term *eucoiliform* has been used for primary larvae of this type. James (1928) compares the early stages of larvae of the Eucoilinae to the embryonic phases of other insects, which according to Berlese have protopod, polypod, and oligopod phases. James assumes without actual observation that the second-stage larva of *T. rapae* bears leg-like appendages like some other species with eucoiliform larvae. No leg-like appendages were found on larvae later than the first stage, which is of the protopod type.

Reproductive Organs

Male

The male reproductive organs (Fig. 13) are similar to those of most Hymenoptera and consist of the paired testes, the paired vasa deferentia, and a vesicula seminalis attached to each vas deferens. The vasa deferentia join in a common ejaculatory duct, which opens into the aedoeagus.

Female

There are paired ovaries, each with 16 to 20 ovarioles (Fig. 14). In gravid females there are three well-developed eggs present in each ovariole. These are arranged one above the other with the pedicel of one egg extending alongside and beyond the body of the egg anterior to it. As there are no nutritive cells, the ovarioles are of the panoistic type (Snodgrass, 1935). Short oviducts connect the ovaries to the common genital duct. The spermatheca is a small, round, flat pouch situated dorsally on the common genital duct. Two large accessory glands are connected to the median genital duct caudad of the spermatheca.

The external genitalia are well developed and resemble those of *Pseudeucoila bochei* Weld as described by Jenni (1951). The ovipositor, when extruded, is longer than the body of the female. When at rest it is retracted within the abdomen, except for a small portion of the tip. The muscles controlling the ovipositor are very well developed and occupy a considerable portion of the abdomen.

Behaviour and Development

Behaviour of Adults

Adults of *T. rapae* are sluggish in their movements and are not strong fliers. Response to light is not marked and in cages as many adults may be found resting

on the parts of the cage away from the light as on the lighted side. Unlike *Aleochara bilineata* Gyll. and *A. bipustulata* (L.), the staphylinid parasites of *Hylemya* spp., adults of *T. rapae* do not show any tendency to hide. Copulation may occur immediately upon emergence and requires from half a minute to a minute. If hosts are available, oviposition by mated or unmated females may take place within a few hours of emergence.

Oogenesis and Oviposition

Dissection of freshly emerged females revealed the presence of large numbers of mature ova. This sexual maturity at emergence is reported for other cynipids, namely, *Psilodora rufocincta* Kieff. and *Neralsia armata* (Say) (Roberts, 1935).

Except for the very small portion of *Hylemya* spp. maggots that are in the parts of the plant above ground, all the larvae attacked by *T. rapae* are not only below the surface of the ground but are embedded in the plant tissues, in many cases to a considerable depth. Undoubtedly some larvae are inaccessible to the parasites, but in the laboratory the parasites showed considerable searching ability, penetrating as far as half an inch into the burrows made by the maggots. Where maggots were relatively near the surface, the females attacked them through the burrow or directly through the plant tissues. Location of the host larva may require considerable time but the act of oviposition does not occupy more than one minute.

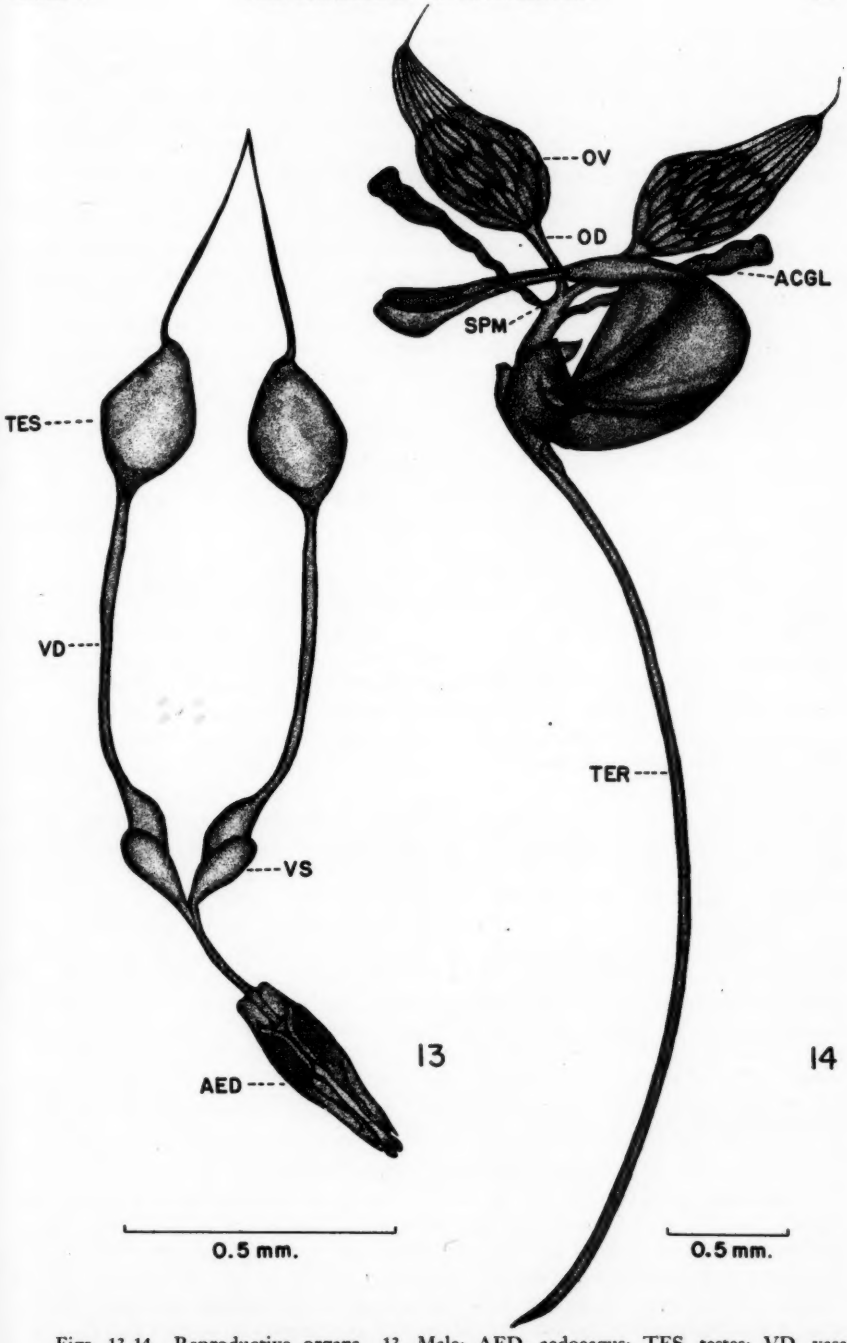
In contrast with James (1928), who found that females would not oviposit in bright light or without the pieces of plant containing the larvae being buried in soil, females oviposited readily in bright, natural or artificial light. The presence of the food plant was not necessary; oviposition took place in naked larvae that had been removed from the plant and washed. Larvae placed between moist filter papers were quickly located by the females.

Other authors (James, 1928; Moltschanova, 1930) state that only first- and second-instar larvae are attacked. In the present work all stages were attacked and development occurred in all but late-third-instar larvae. In these the integument is so thick that the parasites have difficulty inserting their ovipositors. Undoubtedly in nature more very young larvae are attacked than older ones but this is probably because they are more readily accessible.

In contrast with James (1928), who did not find more than two eggs in one host, in the laboratory as many as 14 eggs were found but in hosts collected in the field never more than five. Where large numbers of hosts are present, most of the maggots contain only one egg. It may be concluded that normally the parasite deposits but one egg at a single thrust and that where several eggs are present there has been more than one attack.

Larval Development

At hatching, the head and caudal appendage of the larva break through the chorion but the ruptured chorion, somewhat cylindrical in form, remains around the larva for several days. From oviposition to hatching required about 96 hr. at 75°F. and a longer period at summer ground temperatures. Large numbers of dissections did not reveal any second-instar parasite larvae in host larvae, but some first-instar larvae were found in newly formed host puparia. The first larval stage continues, therefore, until the host puparium is formed. Where a host larva was attacked early in the first stage, the first stage of the parasite was of longer duration than where the host was attacked in the late-second or early-third stage. Temperature, through its effect on the development of the host, may also affect the duration of the first stage. The first stage may last from a few days to weeks, depending on these factors.



Figs. 13-14. Reproductive organs. 13, Male; AED, aedoeagus; TES, testes; VD, vasa deferentia; VS, vesicula seminalis; 14, Female; ACGL, accessory gland; OD, oviduct; OV, ovary; SPM, spermatheca; TER, terebra.

The second and third instars are of relatively short duration, lasting, at 75°F., not more than five or six days. Once the pupal characters are assumed by the host inside its puparium, development of the parasite is rapid. Shortly after the formation of the third instar, the parasite leaves the host pupa through a hole that it gnaws near the head region, dorsad. It takes up a position facing forward on the dorsal part of the host and feeds at the hole from which it made its exit. Since the larva in this stage occupies positions both inside and outside the host, it must be capable of respiration through its integument (apneustic) and by means of its spiracles. The external feeding stage of the third-instar larva lasts one to two days. After the fourth-instar larva is formed, feeding continues until all that remains of the host pupa is the cuticula. A few days after feeding is finished the meconium is voided. It appears as dark, irregular blotches in the posterior end of the host puparium. The fourth stage may last about two weeks to several months, depending on temperature and other factors related indirectly to temperature.

There is no cocoon.

Pupation and Emergence

The pupal period lasts approximately one week. The pupa, in almost all cases, is orientated in the same position as the host. At emergence the adult gnaws an irregular hole in the puparium. During the gnawing there is considerable movement. The opening usually involves from one-half to three-quarters of the circumference of the cephalic region of the puparium. The earliest emergents are largely males.

Hibernation

T. rapae hibernates as a fourth-stage larva in the puparium of the host. A comparatively small number of parasites succumb to winter conditions or during artificial storage in the laboratory. In the laboratory, where conditions were such that many unparasitized hosts died, a smaller proportion of parasites died.

The irregular development of *T. rapae* and the fact that some of its first generation, as in *H. brassicae*, do not complete their development until the next year suggest that the development of the parasite is governed or at least influenced by the development of the host. It is reasonable to assume that the parasite has the same number of generations as the host.

Specimens of *T. rapae* that enter hibernation are of two classes, those that have developed in univoltine hosts and that may have been in the fourth stage for some time, and those that are at or near the fourth stage at the onset of cold weather. In collections of *H. brassicae* made at the harvest time of swede turnips, the parasites were largely in the fourth stage, whereas in collections of *H. floralis* many were in earlier stages. This is probably because *H. floralis* develops more slowly. Development of the parasite may continue at relatively low temperatures and those parasites that have not reached the fourth stage may continue their development in the autumn.

Competition with Other Parasites

The only parasites that are abundant enough to compete with *T. rapae* are the staphylinids *A. bilineata* and *A. bipustulata*. The attack by *T. rapae* occurs well in advance of that by the beetles. However, the two species of *Aleochara* feed externally on the pupae and their attack may and usually does occur before the *T. rapae* larvae leave the host and assume an external feeding position. Where a larva of *Aleochara* sp. has become established in a puparium before the *T. rapae* larva is in the external position, it feeds on both the host and the *T. rapae* larva, killing the latter. In all cases observed the larva of *Aleochara* sp. was the survivor.

Effect of Parasite on Host

Puparia of *Hylemya* spp. parasitized by *T. rapae* are smaller than unparasitized puparia of the same species. For example, parasitized puparia of *H. floralis* may be as small as 3.8 mm. in length and 1.45 mm. in diameter, whereas unparasitized puparia are about 7 mm. in length and 2.5 mm. in width. Not all parasitized hosts are so greatly reduced in size, however, some parasitized puparia of *H. floralis* being 6.13 mm. in length and 2.44 mm. in diameter. The amount of reduction is related to the point in the development of the host at which parasite attack takes place. Attack early in the first instar results in smaller size of the host than attack in the late-second or early-third instar. The smallness of parasitized puparia varies in the three main species studied. The host species in order of their normal size are *H. cilicrura, H. brassicae*, and *H. floralis*. Early-attacked hosts of all species form puparia of comparable size, in spite of the great difference in ultimate size if unparasitized. This is because first-instar larvae of all these species are comparable in size and the differentiating growth takes place largely in the third instar.

Summary

Trybliographa rapae (Westw.), a parasite of several species of *Hylemya*, is widely distributed in Europe and Canada and was observed to destroy up to 45 per cent of the hosts. *T. rapae* undergoes hypermetamorphosis; the first-stage larva is eucoiliform. The third-stage larva, undescribed previously, has a single pair of spiracles; the fourth-stage larva has nine pairs. Eggs are usually laid in first- or second-stage larvae but may also be laid in third-stage larvae. Larval development takes from a few weeks to several months. The winter is passed in the puparium of the host. The number of generations per year depends on the development of the host. Puparia of parasitized hosts are small. Where host puparia containing *T. rapae* larvae are attacked by *Aleochara bilineata* Gyll. or *A. bipustulata* (L.), the *T. rapae* larvae die and *Aleochara* sp. usually survives.

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Common Sawflies Feeding on White Birch in the Forested Areas of Manitoba and Saskatchewan[1]

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Introduction

Twelve species of sawflies are common on white birch (*Betula papyrifera* Marsh.) in the forested areas of Manitoba and Saskatchewan. They also occur in Eastern Canada and the United States. A key is presented at the end of the paper by which the late instars of these twelve species can be identified. The immature forms of these species were described by Dyar (1893, 1895a, 1895b, 1895c), Middleton (1915, 1922) and Riley (1890). Unfortunately these descriptions are scattered in several publications, and in most cases the names of the genera or species in the original descriptions have been changed (Ross 1951). This paper brings together the current nomenclature and some biological information on these species.

Life History Notes

Hosts

Only six of the twelve common species of birch-feeding sawfly larvae are known to occur solely on birch in Manitoba and Saskatchewan. These are *Empria multicolor* (Norton), *Croesus latitarsus* Norton, *Nematus pinguidorsum* Dyar, *Nematus hyalinus* (Marlatt) *Pristiphora siskiyouensis* Marlatt and *Nematinus unicolor* (Marlatt). The remaining six species also occur on a variety of other hosts, as shown in Table 1. All species have been collected more frequently from birch than from any other host with the exception of *Trichiosoma triangulum* Kirby which occurs most frequently on willow, and to a lesser extent on poplar and birch. This species also differs from the others in that it feeds on a greater variety of hosts. It will be noted from Table 1 that each of these six species also occurs commonly on alder. Only *Arge pectoralis* (Leach) and *Dimorphopteryx pinguis* (Norton) were not collected from willow.

Seasonal Occurrence

In the early part of June, larvae of *N. hyalinus* (Marlatt), *C. latitarsus* Norton, *P. siskiyouensis* Marlatt, *T. triangulum* Kirby and *E. multicolor* (Norton) are present in the field. In the latter part of June larvae of *N. pinguidorsum* Dyar and *A. clavicornis* (Fabricius) can be collected. Larvae of *D. pinguis* (Norton), *N. unicolor* (Marlatt), *P. pallipes* (Lepeletier), *C. americana americana* Leach, and *A. pectoralis* (Leach) are present in the early part of July.

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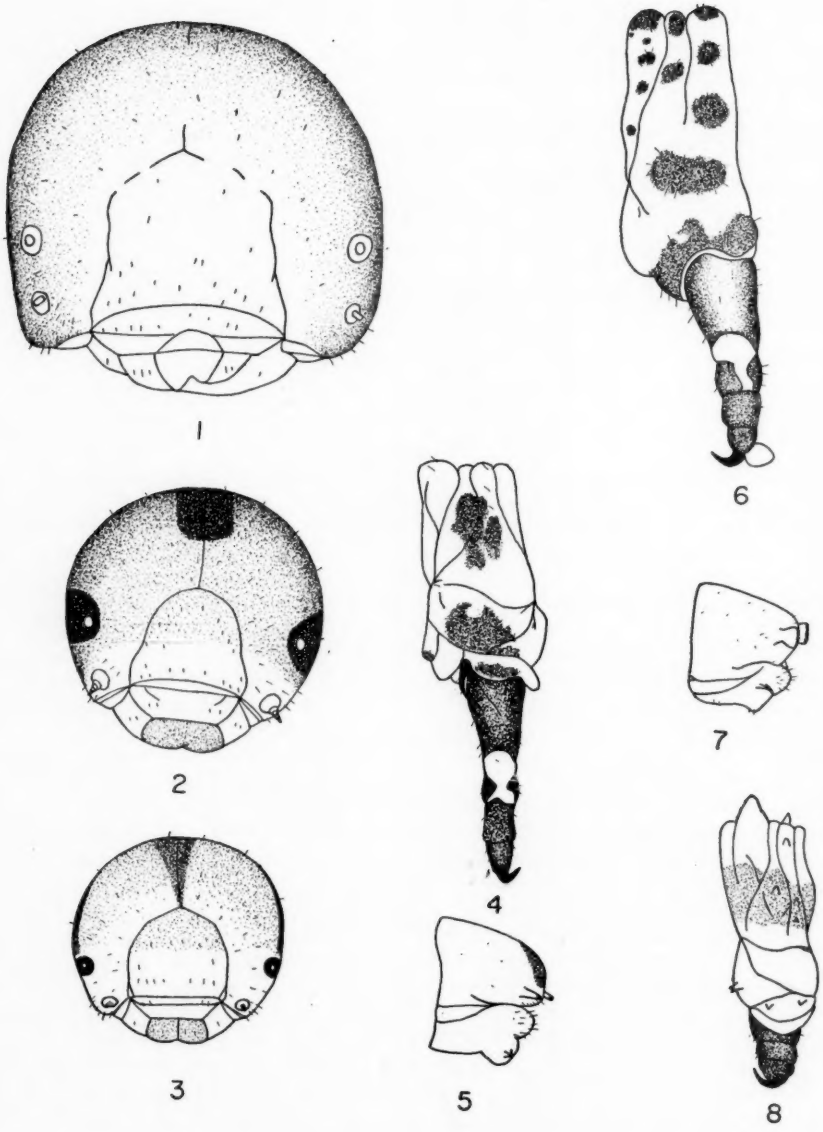
TABLE I

Host trees and shrubs from which sawfly larvae were collected

Species	Host Trees and Shrubs								
	Birch	Alder	Willow	Hazel	Saskatoon	Cherry	Hawthorn	Poplar	Elm
Trichiosoma triangulum Kirby	X	X	X	X	X			X	X
Arge clavicornis (Fabricius)	X	X	X			X			
Cimbex americana americana Leach	X	X	X					X	X
Arge pectoralis (Leach)	X	X		X			X		
Priophorus pallipes (Lepeletier)	X	X	X			X			
Pristiphora siskiyouensis Marlatt	X								
Dimorphopteryx pinguis (Norton)	X	X			X				
Empria multicolor (Norton)	X								
Croesus latitarsus Norton	X								
Nematus pinguidorsum Dyar	X								
Nematus hyalinus (Marlatt)	X								
Nematinus unicolor (Marlatt)	X								



Figs. 1-3; cephalic view of head capsule. 1. *Cimbex americana americana* Leach 2. *Empria multicolor* (Norton) 3. *Pristiphora siskiyouensis* Marlatt.

Figs. 4, 6, and 8; lateral view of mesothorax. 4. *Croesus latitarsus* Norton 6. *Arge pectoralis* (Leach) 8. *Dimorphopteryx pinguis* (Norton).

Figs. 5 and 7; lateral view of caudal segment. 5. *Nematus pinguidorsum* Dyar 7. *Nematus hyalinus* (Marlatt)

All the species except *N. hyalinus* (Marlatt) and *E. multicolor* (Norton) may be collected from birch in September. Larvae of *A. clavicornis* (Fabricius), *N. unicolor* (Marlatt), *A. pectoralis* (Leach), *C. americana americana* Leach and *T. triangulum* Kirby have been collected in October in the Prairies.

Method of Feeding

All the sawfly larvae discussed are external feeders. Except for the very early stages, they exhibit two distinct types of feeding. Larvae of *D. pinguis* (Norton), *E. multicolor* (Norton), *P. pallipes* (Lepeletier), and *N. unicolor* (Marlatt) feed flat on the leaf eating a hole through it. Larvae of the other species cling to the edge of the leaf when feeding. Most of the species are solitary feeders, the exceptions being *A. pectoralis* (Leach) and *C. latitarsus* Norton, which are gregarious. Larvae of *A. clavicornis* (Fabricius) are known to be gregarious, but specimens were generally collected individually in Manitoba and Saskatchewan.

Abundance and Damage

Forest Insect Survey records from 1945 to 1952 indicate that the majority of the species studied caused little damage although the gregarious feeders caused the most defoliation. The most conspicuous damage during this period was caused by *A. pectoralis* (Leach) which severely defoliated white birch in south-eastern Manitoba during 1947 and 1948. Since then, however, damage has been negligible. Populations of *C. latitarsus* Norton have not shown any appreciable fluctuations, and defoliation caused by this insect has remained very light.

During the period 1945 to 1952 there has been an increase in the number of samples containing *A. clavicornis* (Fabricius) and *N. unicolor* (Marlatt). The amount of defoliation caused by these species, however, has been negligible to very light.

Number of Generations

Collections and rearing records indicate that the majority of the species discussed here have only one generation a year in the Prairies. The occurrence of a second or partial second generation has been observed in the following species: *P. siskiyouensis* Marlatt, *P. pallipes* (Lepeletier), *C. latitarsus* Norton, and *N. pinguidorsum* Dyar.

Method of Overwintering

Larvae of *E. multicolor* (Norton) and *D. pinguis* (Norton) overwinter in earthen cells in the ground. All the other species studied pass the winter in cocoons. *Arge pectoralis* (Leach), *A. clavicornis* (Fabricius) and *P. pallipes* (Lepeletier) construct their cocoons in leaf litter. Cocoons of *N. unicolor* (Marlatt) and *C. latitarsus* Norton are constructed in topsoil. The other species form their cocoons in either litter or topsoil.

Key to the Common Sawfly Larvae on White Birch

1. Thoracic legs with a distinct empodium next to claw (Fig. 6) 2
   Thoracic legs without a distinct empodium next to claw (Figs. 4, 8) 3
2. Head with dark streak along epicranial suture; antennae flat; 6 distinct uropods and postpedes ..... *Arge clavicornis* (Fabricius)
   Head without streak along epicranial suture; antennae cone shaped; 5 distinct uropods and postpedes ..... *Arge pectoralis* (Leach)
3. Thoracic legs with 5 segments (Fig. 4) 4
   Thoracic legs apparently 4-segmented, the trochanter being obsolete (Fig. 8); epiproct with 4 large spines; tubercles on body; 2 large projections on prothorax and a single projection on mesothorax ..... *Dimorphopteryx pinguis* (Norton)
4. Larvae with a pair of caudal protuberances (Figs. 5, 7) 5
   Larvae without caudal protuberances 7

5. Caudal protuberances truncate and enlarged at the tip (Fig. 7); markings on head as in Fig. 3 ..... *Nematus hyalinus* (Marlatt)
   Caudal protuberances not truncate or enlarged at the tip 6
6. Caudal protuberances longer than wide (Fig. 5); body with yellow fat-patches along subdorsum; pink triangular patch on epiproct; markings on head as in Fig. 3 ..... *Nematus pinguidorsum* Dyar
   Caudal protuberances scarcely longer than wide; body with 11 fuscous spots along side; fuscous patch on epiproct; no markings on head ..... *Croesus latitarsus* Norton
7. Antennae 1-segmented (Fig. 1); cardo and stipes with prominent triangular projection 8
   Antennae 4- or 5-segmented (Figs. 2, 3); cardo and stipes without triangular projection 9
8. Body with black middorsal stripe and lateral warts ..... *Cimbex americana americana* Leach
   Body without stripe or warts; light orange or brown patch across vertex ..... *Trichiosoma triangulum* Kirby
9. Head with dark brown or fuscous patch on top of head and around each eye (Fig. 2) 10
   Head without patch on top of head or around each eye (Figs. 1, 3) 11
10. Setae on head and body longer than antennae; head freckled in appearance ..... *Priophorus pallipes* (Lepeletier)
    Setae on head and body not as long as antennae; not freckled in appearance ..... *Empria multicolor* (Norton)
    Shape of body not tadpole-like; markings on head as in Fig. 3; yellow-green addorsal dorsolateral stripe (fat bodies) on abdomen and part of thorax ..... *Nematinus unicolor* (Marlatt)
    Shape of body not tadpole-like; markins on head as in Fig. 3; yellow-green addorsal line (fat bodies) on body; 3 yellow-green lines (fat bodies) on posterior segments ..... *Pristiphora siskiyouensis* Marlatt

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Note on Infra-red Lamp for Drying Inflated Larvae

By D. A. Ross and J. K. Harvey
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The following technique employed at the Vernon Laboratory greatly facilitates the preparation of inflated larval specimens. Inflated larvae are dried over a reflector infra-red heat lamp (250 watts), clamped to a titration stand. The standard heat lamp with an aluminum reflector, and the red bowl heat lamp with a nickel reflector have been tested; the latter is preferable because it radiates more heat with reduced glare.

Use of the infra-red lamp has decided advantages over the old style oven; it is more convenient, it dries the specimens more quickly without scorching the skin and setae, and does not affect some colours as greatly.

Food Relations of the Wheat Stem Sawfly, *Cephus cinctus* Nort. (Hymenoptera: Cephidae)[1]

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It has been shown by Farstad (1940) and Platt (1946, 1948) that resistance in wheat to the wheat stem sawfly, *Cephus cinctus* Nort., is positively correlated with solidness of stem. Under certain environmental conditions the resistant variety Rescue becomes susceptible to sawfly damage. The nature of this resistance is unknown, but a study of the nutritional requirements of *C. cinctus* may reveal it and perhaps assist in the development of new resistant varieties. The preliminary phases of this project were conducted with the following objectives: to study the anatomy of the larval organs of ingestion and digestion; to determine the plant tissues ingested by the larva; and to study the hydrolytic enzymes present in feeding larvae.

Organs of Ingestion, Digestion, and Excretion of the Larva

Materials and Methods.—Larvae were collected from infested wheat stems in the vicinity of Lethbridge, Alberta. Fourth- and fifth-instar larvae, approximately half an inch long, were selected for dissection. Bouin's solution was used as the killing and fixing agent. Microtome sections were made from paraffin-embedded material, and whole mounts were prepared from larvae cleared in oil of cloves. All nomenclature used is that of Snodgrass (1935).

Head and Mouth Parts.—The mandibles are of the phytophagous biting and chewing type, with well-defined incisor and molar regions. The maxillae are closely associated with the labium and hypopharynx to form an "underlip complex". The ligula is a simple flap bearing the orifice of the labial glands in its ventral surface (Fig. 5).

The head capsule is strengthened along its subgenal region by a strong pleurostomal ridge bearing the mandibular articulations. Anterior to the mandibles, a pair of epistomal bars extend to the anterior tentorial pits. These bars are connected between the pits by an epistomal ridge (Fig. 3). The tentorium consists of a pair of anterior arms and a strong tentorial bridge, which originates in the postoccipital suture (Fig. 4).

The labial glands (Figs. 1, 6) are a pair of elongate tubes, which lie free in the body cavity, one on each side of the alimentary canal. Each tube is U-shaped, the posterior ends terminating near the ventricular valve. The anterior part encircles the gastric caecum and is enlarged to form a reservoir. From this, a duct leads forward to form a common tube with the corresponding duct from the other reservoir. This tube has its outlet in the ventral surface of the ligula. These glands produce some hydrolytic enzymes as well as the secretion for the construction of the overwintering case.

Alimentary Canal.—The stomodaeum (Fig. 2) is invaginated into the anterior end of the mesenteron to form the stomodaeal valve. Two ovate gastric caeca (Figs. 1, 7) empty into the anterior end of the mesenteron. The peritrophic membrane is continuous with the ventricular epithelium and appears to be formed from the entire surface of the latter (Fig. 8). At the posterior end of the mesenteron the epithelium of the ventriculus projects into the proctodaeum, forming the ventricular valve. The proctodaeum is differentiated into an anter-

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2Assistant Entomologist.

ior intestine and a posterior intestine, or rectum (Fig. 11). In the rectum the lining projects into the lumen as six ridge-like structures (Fig. 10).

The larva possesses ten Malpighian tubes, which empty into the alimentary canal through a central opening in the ventral surface of the proctodaeum (Fig. 9). All the tubes lie free in the body cavity; four extend to the anterior end of the mesenteron, four proceed caudally to the area of the rectum, and two extend in an anterior direction, reverse, and terminate in the caudal area (Fig. 1).

Plant Tissues Ingested

All the nutrients required for growth, development, and reproduction of *C. cinctus* are obtained during the larval stage. Although Farstad (unpublished notes) has observed the adults feeding in flowers, they mate and produce viable eggs without feeding.

The anatomy of the culm of the wheat plant has been described by Percival (1921). An epidermis of narrow, elongate cells lies on the outside. The hypoderm, consisting of lignified fibres, is situated next to the epidermis and contains parallel narrow strips of assimilating parenchyma. Colourless ground parenchyma extends from the hypoderm to the pith cavity. Vascular bundles are distributed symmetrically in the ground parenchyma.

Materials and Methods.—Serial and hand sections were made from infested stems. Frass was collected and examined. The iodine test was applied to sections of Thatcher wheat to test for the presence of starch.

Because wheat stem sawfly larvae had never been observed while feeding, a method was developed whereby the processes of feeding, growth, and secretion of the cocoon could be watched. Glass tubing with a bore of 5.0 mm. was cut into three-inch lengths. Wheat stems were split longitudinally and each half was placed in a separate tube. Larvae were inserted, the ends of the tubes plugged with cotton wool, and the tubes placed in a vertical position. The stem sections were renewed every 24 hours. This method may be used in the artificial feeding of the larva in further nutritional studies.

Results and Observations.—Most larvae survived approximately 10 days, although two remained alive for 22 days, matured, and ceased feeding.

As was suspected, the S-shape of the larva has a functional purpose. The pygidium is braced against the lumen wall. An opposing thrust is provided by the ventral surface of the abdomen against the opposite wall. The anterior part of the body is curved so that the mandibles may be inserted into the plant. Plant tissues are removed with a tearing motion, the head is raised slightly as the tissues are eaten, and the mandibles are again plunged into the wall. Much of the tissue removed is discarded.

When two larvae were placed in one tube, both with their heads directed upward in the stem, the posterior larva, on coming in contact with the anterior, attacked and fed on it. Cannibalism undoubtedly provides a supplementary source of food but is not essential.

The larva is a voracious feeder and within 48 hours can reduce a three-inch half-section of wheat to hypoderm and frass. In some tubes even the cotton plugs were partially eaten.

In Thatcher wheat the assimilating parenchyma of the hypoderm disappears where it is covered by the leaf sheath. The node is completely filled with pith containing chloroplastids. These bodies are also found in the outer parenchyma of the internodes and, in decreasing numbers, in parenchyma cells toward the pith cavity. Starch granules are present in the parenchyma between bundles at the node and part way up the internode.

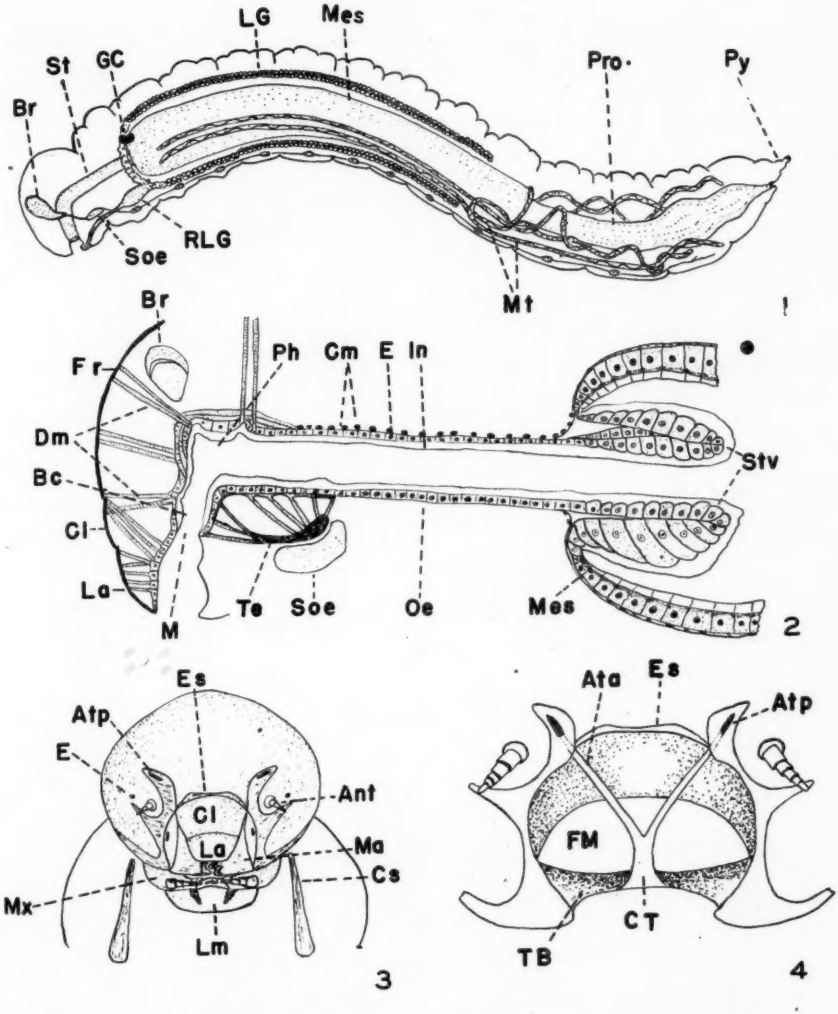

Fig. 1. Internal organs of wheat stem sawfly larva (feeding stage). Br, brain; GC, gastric caecum; LG, labial glands; Mes, mesenteron; Mt, Malpighian tubules; Pro, proctodaeum; Py, pygidium; RLG, reservoir of labial glands; Soe, suboesphageal ganglion; St, stomodaeum.

Fig. 2. Stomodaeum, longitudinal section. Bc, buccal cavity; Br, brain; Cl, clypeus; Cm, circular muscles; Dm, dilator muscles; E, epithelium; Fr, frons; In, intima; La, labrum; M, mouth; Mes, mesenteron; Oe, oesophagus; Ph, pharynx; Soe, suboesophageal ganglion; Stv, stomodaeal valve; Te, tentorium.

Fig. 3. Head, ventral view. Ant, antenna; Atp, anterior tentorial pit; Cl, clypeus; Cs, cervical sclerite; E, larval eye; Es, epistomal suture; La, labrum; Lm, labium; Ma, mandible; Mx, maxilla.

Fig. 4. Tentorium, ventral view. Ata, anterior tentorial arm; Atp, anterior tentorial pit; CT, corporotentorium; Es, epistomal suture; FM, foramen magnum; TB, tentorial bridge.

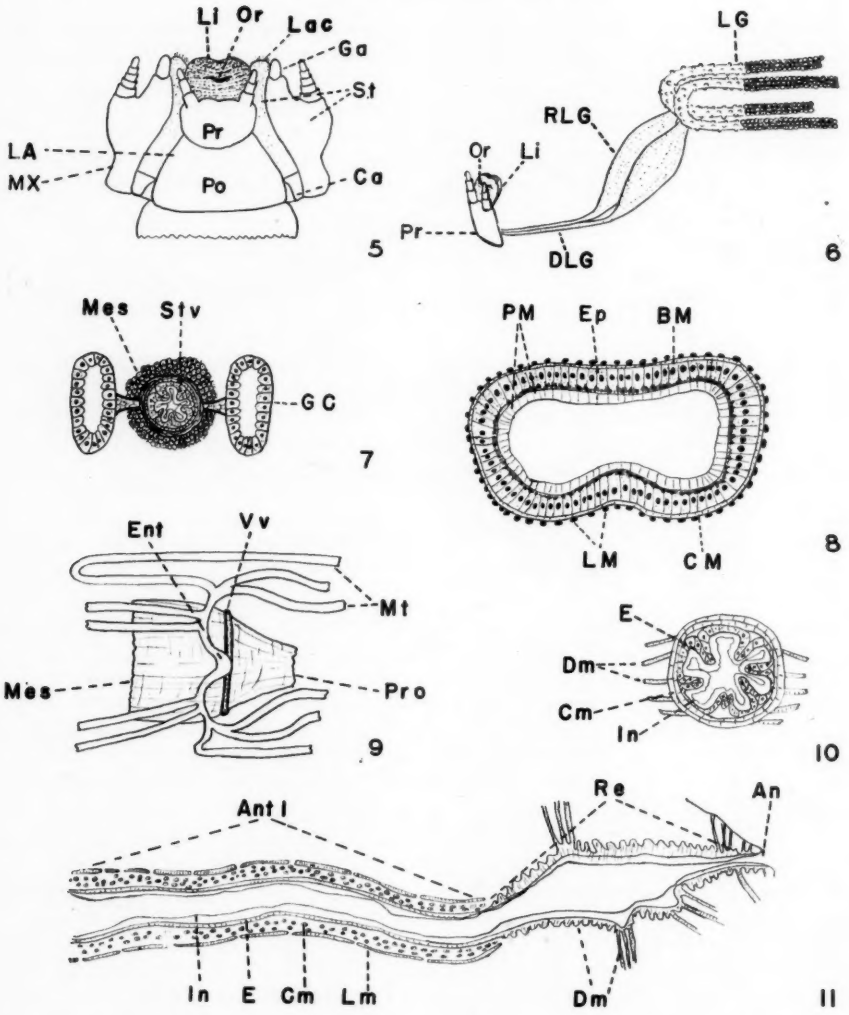

Fig. 5. Maxillae and labium, ventral view. Ca, cardo; Ga, galea; LA, labium; Lac, lacinia; Li, ligula; Mx, maxilla; Or, orifice of labial glands; Po, postmentum; Pr, prementum; St, stipes.

Fig. 6. Labial glands, lateral view. DLG, ducts of labial glands; LG, labial glands; Li, ligula; Or, orifice of labial glands; Pr, prementum; RLG, reservoir of labial glands.

Fig. 7. Gastric caeca, cross section. GC, gastric caecum; Mes, mesenteron; Stv, stomodaeal valve.

Fig. 8. Mesenteron, cross section. BM, basement membrane; CM, circular muscles; Ep, epithelium; LM, longitudinal muscles; PM, peritrophic membrane.

Fig. 9. Malpighian tubules, ventral view. Ent, entrance of Malpighian tubules into gut; Mes, mesenteron; Mt, Malpighian tubules; Pro, proctodaeum; Vv, ventricular valve.

Fig. 10. Proctodaeum (rectal area), cross section. Cm, circular muscles; Dm, dilator muscles; E, epithelium; In, intima.

Fig. 11. Proctodaeum, longitudinal section. An, anus; Ant I, anterior intestine; Cm, circular muscles; Dm, dilator muscles; E, epithelium; In, intima; Lm, longitudinal muscles; Re, rectum.

The larva of *C. cinctus* removes parenchyma and vascular tissues, parenchyma constituting the main part of the tissues removed. The larva seldom removes the hypoderm, although Farstad (1) reports that in very dry weather the larva will chew through it and into the leaf sheath. One stem showing this type of feeding is illustrated (Fig. 12, B), and the normal type of feeding is shown in Fig. 12, A, C. In traversing the solid node, the larva tunnels through the bundles

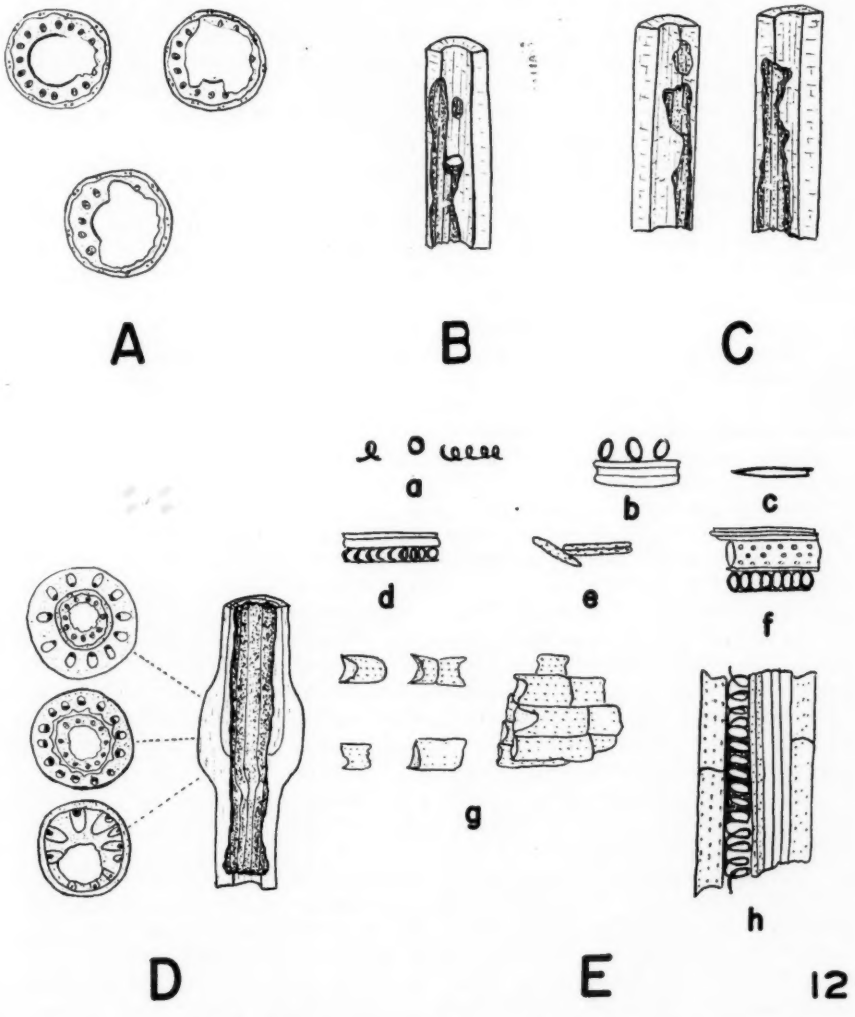

Fig. 12. Infested Thatcher wheat stems and tissues ingested by sawfly larvae. A, cross sections of internodes showing typical feeding. B, longitudinal section of internodes showing excessively deep feeding. C, longitudinal section of internode showing typical tunnelling pattern. D, longitudinal and cross sections of node of infested stem. E, tissues of wheat stem found in the larval gut: a, primary xylem, annular and spiral vessels; b, c, d, annular vessels and fibres; e, tracheids; f, annular vessel, pitted vessel, fibres; g, parenchyma; h, large fragment of vascular and parenchyma tissue.

at the base and, as it ascends, removes only parenchyma (Fig. 12, D). As it matures, it removes so much parenchyma and vascular tissue that the stem becomes translucent. Vascular bundles are severed at intervals throughout the internode. This reduces the nutrients available to the developing wheat kernels, resulting in reduction in yield (Seamans *et al.*, 1945).

The gut of the feeding larva is visible through the body wall as a large green tube. In the mesenteron, fragments of parenchyma and vascular tissues were found as large as 0.6 mm. by 0.3 mm. Twisted and distorted cells, parts of cell walls, and macerated green tissue constitute most of the contents. The hind-gut contains remnants of cells, macerated tissue, and some green matter, although the latter occurs in smaller quantities than in the mid-gut. The larger fragments pass apparently unchanged through the gut. Parenchyma forms the greater part of the contents of the intestinal tract (Fig. 12, E).

The frass, like the material in the hind-gut, was made up of cell fragments and macerated tissues.

These examinations indicate that the larva ingests parenchyma and vascular tissue. Large fragments may pass unchanged through the gut. Partial digestion of the cell walls may occur, although this is not apparent from microscopic examination.

Digestive Enzymes

Materials and Methods.—The technique for testing enzymes qualitatively was based on that described by Parkin (3). Third- to fifth-instar larvae, in groups of 10 to 20, were used in each test. Tissues were dissected from freshly killed individuals, washed in distilled water, and triturated for lipase and carbohydrases in distilled water and for proteases in glycerol. The suspension was made up to a volume equivalent to one cubic centimeter for each insect dissected. This was divided into two equal parts; one part was boiled to serve as a control. Substrates were added to the suspensions in test tubes. The mixtures were then covered with a layer of toluol, corked, and incubated at 91° to 97°F. for 24 hours. After incubation, tests were conducted for hydrolyzed products of the substrate produced by enzymatic action. Most tests were repeated several times.

Benedict's reagent was used to test for reducing sugars produced by the action of amylase, sucrase, and cellulase. For maltase and lactase Barfoed's reagent was used to detect the production of monosaccharides. Similar tests with Thatcher wheat stem tissues were conducted for amylase and sucrase.

The colour release method, with stained fibrin as described by Parkin (3), was used to test for pepsin and trypsin.

To detect lipase, the tissue suspension was mixed with alkaline milk containing phenolphthalein. Loss of the pink colour indicates the production of fatty acids by the action of lipase.

In these experiments, concentrations of substrate, incubation time, the incubation temperature were controlled, although not necessarily at the optimum for enzymatic activity. The medium Hp and enzyme concentration were not controlled. Consequently, negative results may have been obtained as a result of unfavourable conditions rather than through the absence of the enzyme itself.

Results and Discussion.—Table I shows that amylase, sucrase, and cellulase are present in immature sawfly larvae. Negative results were obtained in tests for lactase and maltase. Amylase and sucrase were found in tissues of the mid-gut and labial glands but not in the hind-gut.

The source of cellulase is probably in the intestinal tract, although nine of the 12 tests produced negative results (Table I). Because negative tests with these methods have less validity than positive results, it may be assumed that

TABLE I

Tests for carbohydrate enzymes in tissues from groups of 10 to 20 wheat stem sawfly larvae incubated at 91° to 97°F. for 24 hours

Enzyme	Substrate		Tissue		Number of tests	
	Composition	Vol., cc.	Composition	Vol., cc.	Positive	Negative
Amylase	1% starch solution	10	Complete larvae	10	6	0
		10	Complete gut	10	9	0
		10	Mid-gut	10	1	2
		10	Hind-gut	10	0	2
		5	Labial glands	5	3	0
Sucrase	2% sucrose solution	10	Complete larvae	1	3	0
		10	Complete gut	1	3	0
		10	Mid-gut	1	3	0
		10	Hind-gut	1	0	2
		5	Labial glands	1	2	0
Cellulase	Shredded filter paper solution	20	Complete larvae	10	5	0
		10	Complete gut	5	3	9
		10	Mid-gut	5	0	2
		10	Hind-gut	5	0	2
		5	Labial glands	2	0	2
Lactase	1% lactose solution	15	Complete larvae	15	0	1
		10	Complete gut	10	0	1
Maltase	1% maltose solution	2	Complete larvae	2	0	1

TABLE II

Tests for carbohydrate enzymes in tissues from Thatcher wheat stems incubated at 97°F. for 24 hours

Enzyme	Substrate	Volume cc.	Number of tests	
			Positive	Negative
Amylase	1% starch solution	10	1	0
Sucrase	2% sucrose solution	10	1	0

cellulase is present in the gut. It may be produced by larval gut tissue, by micro organisms in the gut, or by ingested stem tissue.

Table II shows that amylase and sucrase are present in stem tissues of Thatcher wheat.

Trypsin and pepsin were not shown to be present in feeding larvae (Table III). The fibrin, dyed with congo red, that was used in tests for trypsin tended to release its stain in both test and control. Two of three tests for trypsin were invalidated because of this defect. It is remarkable that trypsin was not detected. However, Parkin (1936) believed that he failed to find proteinase because of the great dilution of the tissue suspension. This may explain the negative trypsin tests with sawfly larvae.

In testing for lipase, it was hard to detect the colour change from pink to white. Bacterial action in the substrate obscured results in one of the tests. Although the lipase test was repeated four times, only one gave positive results (Table III). Results were inconclusive, but the presence of lipase in the larval gut was indicated.

Summary

The anatomy of the organs of ingestion, digestion, and excretion of the immature larva of *Cephus cinctus* is described and illustrated.

The larva ingests parenchyma and vascular tissues. A method was developed for observing larvae feeding on longitudinal sections of wheat stem in glass tubes. This technique may be useful in further studies on sawfly nutrition.

TABLE III

Tests for lipase and proteases in tissues from groups of 10 to 20 wheat stem sawfly larvae; tissues incubated at 91° to 97°F. for 24 hours

Enzyme	Tissue	Volume cc.	Number of tests	
			Positive	Negative
Pepsin	Complete gut	10	0	1
Trypsin	Complete gut	5	0	1
Lipase	Complete larvae	20	0	1
	Complete gut	10	0	2
	Gut and labial glands	10	1	0

Some digestive enzymes were studied qualitatively. The larva contains enzymes capable of hydrolyzing starch, sucrose, and cellulose. Amylase and sucrase were found in the mid-gut and labial glands but not in the hind-gut. These two enzymes are also present in wheat stems. Cellulase is probably produced in the intestinal tract. Tests for maltase, lactase, pepsin, and trypsin gave negative results. Lipase may be present in the larval gut, but results were not conclusive.

Acknowledgments

The writer acknowledges the guidance and assistance of Dr. C. W. Farstad, Officer-in-Charge, Field Crop Insect Section, Science Service Laboratory, Lethbridge, who suggested this experiment and permitted the reference to some of his unpublished data, and of Professor B. Hocking, University of Alberta, under whose direction the work was completed.

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Notes on the Parasites of *Neodiprion nanulus* Schedl (Hymenoptera: Tenthredinidae)[1]

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Belleville, Ontario

In collecting sawfly eggs, larvae, and cocoons for propagating beneficial insects at the Belleville laboratory, a heavy infestation of a pine sawfly, *Neodiprion nanulus* Schedl, was discovered in 1942 nine miles north of Belleville, on a 25-year-old plantation of red pine, *Pinus resinosa* Ait.; Scots pine, *Pinus sylvestris* L.; and jack pine, *Pinus banksiana* Lamb.

From samples of the eggs collected in the spring of 1943, no parasites emerged.

Cocoons were collected in 1943 from July until the third week of November, at approximately two-week intervals, nine collections being made. Two further collections were made in 1944, one in May and one in September. Samples of the collections, 3205 cocoons in all, were placed singly in one-inch glass vials stoppered with a plug of cotton and were incubated at 23°C. and 65 per cent relative humidity until emergence had ceased. The remaining cocoons were re-incubated in 1945, and those not producing adults were dissected.

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2Agricultural Research Officer.

TABLE I

Numbers of *N. nanulus* and of species of parasites that emerged from cocoons of *N. nanulus* collected near Belleville, Ont., 1943 and 1944

	1943					1944		Total	Percentage of cocoons incubated
	July	Aug.	Sept.	Oct.	Nov.	May	Sept.		
Tenthredinidae									
Neodiprion nanulus Schedl	143	266	524	426	343	22	191	1915	59.75
Eulophidea									
Dahlbominus fuscipennis (Zett.)	54	133	220	230	261	16	84	998	31.14
Ichneumonidae									
Endasys subclavatus (Say)	2	14	13	13	24	1	2	69	2.15
Mastrus aciculatus (Prov.)	0	2	2	5	4	1	0	14	.44
Lamachus lophyri (Ashm.)	0	1	6	0	2	0	0	9	.28
Delomerista diprionis Cush.	0	0	5	1	2	0	0	8	.25
Euceros fr gidus Cress.	0	0	1	2	3	0	0	6	.19
Agrothereutes lophyri (Nort.)	0	1	2	1	0	0	0	4	.12
Exenterus canadensis Prov.	0	1	1	0	0	0	0	2	.06
Exenterus walleyi Cush.	0	0	0	0	0	1	0	1	.03
Tachinidae									
Neophorocera hamata (A. & W.)	0	0	0	1	1	0	0	2	.06
Undetermined Hymenoptera (immature)	0	18	14	47	40	3	8	130	4.06
Undetermined Diptera (immature)	1	1	0	0	0	0	3	5	.16
Empty cocoons (predators)	0	4	9	22	7	0	0	42	1.31
Total	200	441	797	748	687	44	288	3205	100.00

The species of parasites and the relative abundance of each are shown in Table I. As there was no significant difference in parasitism in the two collections within each month, the data for each month were totalled.

The table shows that the eulophid *Dahlbominus fuscipennis* was the most common, representing three-quarters of the total parasitism. The ichneumonid *Endasys subclavatus* was second in importance, *Mastrus aciculatus*, *Lamachus lophyri*, and *Delomerista diprionis* following in the order given.

D. fuscipennis, introduced from Europe and released against the European spruce sawfly, *Diprion hercyniae* (Htg.), was the only exotic parasite recovered although four species, including *D. fuscipennis*, had been released against *N. nanulus*. The remainder of the parasites included eight ichneumonid and one dipterous species. Many of the parasites (*D. fuscipennis*, *Neophorocera hamata*) emerged soon after the cocoons were collected; some (*Exenterus canadensis*, *L. lophyri*), however, did not emerge until the following year, and a few (*E. subclavatus*, *M. aciculatus*, *D. diprionis*) emerged in both years. *Exenterus canadensis*, *Exenterus walleyi*, and *N. hamata* parasitize *N. nanulus* larvae in the field before cocoon formation. Others, such as *D. fuscipennis*, *D. diprionis*, and *E. subclavatus*, parastize the larvae or pre-pupae within the host cocoon.

The author is indebted to Mr. G. S. Walley, Systematic Entomology Unit, Entomology Division, Ottawa, for identifying most of the ichneumonid parasites.

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Life-History Studies of *Spaelotis clandestina* (Harr.) and *Polia purpurissata* (Grt.) (Lepidoptera: Phalaenidae) in Low-bush Blueberry Areas in New Brunswick[1]

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Wood (1951) published a list of lepidopterous larvae collected from commercial blueberry fields in Charlotte County, N.B. Among the species consistently collected annually from 1947 to 1952 are the cutworms *Spaelotis clandestina* (Harr.) and *Polia purpurissata* (Grt.). Although notes on both species have been given by various authors, including Crumb (1929, 1932), Gibson (1915), and Phipps (1930), no complete account of their life-histories has been published.

Methods

With minor exceptions both species were reared by the following technique. Partially grown larvae were collected each spring by sweeping the blueberry fields at night with a large insect net. Rearing was done in a field insectary, each specimen being confined in a separate jelly jar and fed daily on fresh blueberry foliage. Adults so obtained were mated to provide successive generations. To keep the larvae alive through the winter months, they were confined in flats of blueberry sod approximately six inches thick. The flats were enclosed by cotton cloth and left out-of-doors all winter. In spite of high winter mortality, enough larvae survived to enable continued study the following spring.

Light- and bait-traps were used to study flight periods, and the gravid females obtained from them provided a supplementary source of fertile eggs. A variety of traps were used at the beginning of the study, the most efficient being a large light-trap, nine feet square and nine feet high, with a board floor and wire screening on all sides. From the centre of each of the four sides a pyramid-shaped funnel was directed inwards and upwards towards the light source, which consisted of two 100-watt bulbs. The funnels served as entrances for the moths. One funnel was mounted on hinges and could be moved so that the operator might enter the cage.

Spaelotis clandestina (Harr.)

Distribution

The w-marked cutworm, *S. clandestina*, occurs in Canada from Nova Scotia to British Columbia (Gibson, 1915), and in Greenland (Phipps, 1930). Crumb (1929) reported that it is a northern species occurring across North America, its southern limit being approximately Kentucky, Missouri, Kansas, Colorado, Utah, Nevada, and California. The insect is commonly found in blueberry fields in New Brunswick and Maine. The larvae attack a wide variety of plants, including small fruits, vegetables, cereals, and grasses. Phipps (1930) reported that in 1929 this cutworm and two other species, *Actebia fennica* Tausch. and *P. purpurissata*, stripped a 50-acre blueberry field in Maine.

Description of Egg

Crumb (1929) described all the stages except the egg.

The eggs appear circular dorsally and ellipsoidal laterally, with dorsoventral striations. They are about 0.75 mm. in diameter and 0.64 mm. in height. When

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deposited they are pale yellow but turn black before hatching. The eggs are laid in haphazard masses, moths in capitvity preferring to deposit them under sand or debris.

Life-History

The duration of the egg stage varied from 27 to 57 days in the insectary. It is probable that the upper limit of this range is typical of eggs in the field. However, in general, eggs laid early in the season required a longer period of incubation than those deposited later. Data on oviposition and duration of egg stage are shown in Table I.

TABLE I

Durations of Mating, Oviposition, and Hatching Periods and of Egg Stage of *S. clandestina*

Year	Mating	Ovipositing	Hatching	Egg, days	
				Range	Mean
1948	Aug. 25–Sept. 19	Aug. 30–Sept. 27	Oct. 2–Nov. 8	27–51	39.7
1949	Aug. 28–Sept. 6	Sept. 2–Sept. 20	Oct. 29–Nov. 26	39–57	48.6
1950	Aug. 19–Sept. 7	Sept. 2–Sept. 18	Oct. 10–Oct. 25	37–45	41.7

The larval stage begins in late October and November and continues until early June, usually a period of about seven months. The larvae pass through five well-defined instars. Head-capsule measurements for each instar were as follows:—

Instar	I	II	III	IV	V
No. measured	33	33	93	78	66
Range, mm.	0.38-0.41	0.58-0.65	0.83-1.15	1.41-1.82	2.18-3.00
Mean, mm.	0.40	0.63	0.99	1.67	2.74

Pupation occurs in the soil, beginning in late May or June. The pupal stage lasts approximately 30 days. Records on pupation and emergence from 1947 to 1951 are shown in Table II. The adults may be found from early July until late in September. Reared moths lived about two months.

There was considerable doubt among earlier workers as to whether this cutworm has one or more generations a year. LaCroix (1936) suggested that there are two generations a year in Connecticut. Crumb (1929) stated that the

TABLE II

Durations of Pupation, Pupal, and Emergence Periods of *S. clandestina*

Year	No. of Pupae	Pupation	Pupa, days		Emergence
			Range	Mean	
1947	30	May 31–June 24	22–33	26.8	July 2–1
1948	34	June 3–27	24–38	30.0	July 11–21
1949	14	June 2–13	24–30	.28.3	June 28–July 8
1950	55	May 30–July 8	27–41	33.7	July 2–Aug. 4
1951	103	May 23–July 4	28–55	32.7	July 9–26

species may be one-brooded with a period of retarded development in the egg stage and possibly in the preoviposition period. Phipps (1930) considered that there is at least a partial second generation under Maine conditions. The present investigation showed that there is but one generation a year in New Brunswick.

Larvae in the second instar appear about the middle of April under normal New Brunswick conditions. They feed at first on the young blueberry buds and later on the foliage, continuing until late in May or early in June, about the time blueberry plants have reached full bloom. Larvae reared in the insectary ceased feeding five or six days before pupating. Pupation takes place in the soil, beginning early in June. Adults begin to appear early in July. After emergence the moths conceal themselves during the day, many of them entering barns or other buildings near the blueberry fields, becoming active only at night. Although they are not readily attracted to light or baits, collections have been made from the middle of July to late in September. Insectary-reared moths spend a period of six to eight weeks before they mate. Oviposition usually occurs about one week after mating, although some moths have oviposited three days and others 15 days after mating. The eggs hatch in late October or early November. The larvae enter the soil shortly after hatching. The winter is passed in the first instar and the larvae moult on emerging from the soil in the following spring.

Natural Control

Parasitism of insectary-reared larvae was low, the highest record being 20 per cent in 1949. Parasites reared were *Microplitis* sp. near *autographae* Mues., *Apanteles laeviceps* Ashm., and *Pterocormus rufiventris* (Brullé). The first two species emerged from mature host larvae, and the last from pupae.

No information was obtained on predators or diseases. Glaser and Chapman (1916), however, isolated a polyhedral disease from larvae of *S. clandestina.*

***Polia purpurissata* (Grt.)**

Distribution

This species has been recorded from Quebec and British Columbia in Canada (Crumb, 1932) and in the United States from Maine to New York and as far west as Utah and Colorado (Phipps, 1930). In New Brunswick it is one of the more common cutworms in blueberry fields. In addition to blueberry plants, it feeds on the shrubs and weeds found in a blueberry field.

Description of Egg and Larva

Descriptions of the pupa and the adult have been published by Crumb (1932) and Phipps (1930).

When laid the egg is creamy white in colour, and appears circular dorsally and ellipsoidal laterally, with dorsoventral striations. It has a diameter of 0.82 mm. and a height of 0.67 mm. During the incubation period it darkens in colour, turning almost black before hatching. In confinement the eggs are laid in rows on the undersides of blueberry leaves or on the sides of the containers. The eggs have not been found in the field.

Immediately after hatching the larva is light brown with indistinct markings. The colour pattern and markings of the first instar are quickly assumed, as follows: a broad, mid dorsal, white stripe occupies most of the dorsum, flanked on each side by two narrow, subdorsal stripes and a broad, white, spiracular stripe similar to the mid-dorsal stripe; the surface between the mid-dorsal and subdorsal stripes is light brown, and that between the subdorsal and spiracular stripes is pale light brown.

With the increase in size through the various instars the white stripes become narrower and more distinct. This is the typical pattern up to and including the third instar. During this instar the colour pattern gradually disappears, and the remaining instars are light mottled brown.

Life-History

The duration of the egg stage varied from eight to 15 days in the insectary. Duration of oviposition and hatching periods and egg stage are shown in Table III.

TABLE III

Durations of Oviposition and Hatching Periods and of Egg Stage of *P. purpurissata*

Year	Ovipositing	Hatching	Egg, days	
			Range	Mean
1948	Aug. 4–14	Aug. 24–25	10–11	11.0
1949	Aug. 4–31	Aug. 14–Sept. 8	8–13	9.9
1950	Aug. 10–Sept. 13	Aug. 16–Sept. 21	8–11	9.3
1951	Aug. 9–Sept. 10	Aug. 20–Sept. 11	10–15	13.2

The larval stage begins about the middle of August, and continues until the middle of June, a period of approximately ten months. The larvae pass through seven instars. Head capsule measurements for each instar were as follows:

Instar	I	II	III	IV	V	VI	VII
No. measured	75	75	75	75	75	18	8
Range, mm.	0.46-0.50	0.64-0.72	0.95-1.06	1.20-1.51	1.56-1.95	2.06-2.60	3.22-4.08
Mean, mm.	0.48	0.68	1.00	1.37	1.73	2.39	3.80

Pupation takes place in the soil in late June and early July. The pupal period usually lasts six or seven weeks. The adults mate and oviposit shortly after emerging. Reared moths lived only a few days after depositing their eggs. The moths are in flight from the last of July until early September. Durations of pupation, pupal periods, and emergence are shown in Table IV. Collection of adults by light- and bait-traps are shown in Table V.

TABLE IV

Durations of Pupation, Pupal, and Emergence Periods of *P. purpurissata*

Year	Pupae	Pupation	Pupa, days		Emergence
			Range	Mean	
1947	13	June 24–July 8	38–52	48.7	Aug. 1–29
1948	18	June 25–July 10	35–50	39.2	Aug. 1–22
1949	35	June 6–29	45–58	51.1	July 31–Aug. 16
1950	24	June 12–July 6	38–57	47.7	Aug. 5–25
1951	12	June 21–July 18	39–61	49.1	Aug. 13–Sept. 4

TABLE V

Collection of *P. purpurissata* by Light- and Bait-Traps

Year	No. Collected	Range of Collection Dates
1948	120	July 30–Sept. 10
1949	154	July 29–Sept. 7
1950	403	Aug. 5–Sept. 16
1951	151	July 25–Sept. 4

This species, like *S. clandestina*, overwinters in the soil as a partially grown larva, but usually in the third or fourth instar. It resumes feeding early in April and continues until late June or early July. Pupation takes place in the soil and adults emerge in late July and throughout August. Mating begins shortly after emergence and eggs are laid during August and early September. The eggs hatch in about ten days and the young larvae begin to feed immediately. The larvae enter the soil during the latter part of November, and remain inactive until the following spring.

Natural Control

Parasitism of insectary-reared material was not very high, although a variety of parasites were reared from this host. The highest percentage parasitism was obtained in 1950, when 35 per cent of the collected specimens were parasitized. One egg mass that remained out of doors was parasitized by *Telenomus* sp., near *graptae* How. *Fabriciella hispida* Toth. and *Ophion* sp. were reared from larvae. *Therion nigrovarium* (Brullé), *Coelopisthia* sp., *Eulophus* sp., *Dibrachys cavus* (Wlkr.), and *Gravenhorstia* sp. were reared from pupae.

Summary

There is one generation of *S. clandestina* a year in New Brunswick. The moths appear early in July after a pupation period of about 30 days. Eggs are laid through September and hatch in October and November. There are five instars. The larvae pass the winter in the first instar.

There is one generation of *P. purpurissata* a year in New Brunswick. The adults emerge in late July and throughout August, eggs are laid in August and early September, and the incubation period lasts about ten days. Winter is passed in the third and fourth instars, there being seven instars in all. Pupation begins about mid June and lasts approximately seven weeks.

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A Relation Between April and May Temperatures[1] and Spruce Budworm Larval Emergence

By A. H. Rose[2] and J. R. Blais[2]

In the spring, spruce budworm (*Choristoneura fumiferana* (Clem)), emerge as second-instar larvae from hibernacula. This emergence may be sudden and is readily detectable in the field. In northwestern Ontario, the sudden appearance of larvae in large numbers was especially spectacular in 1948; that year, very few insects were observed on May 11, but on the following two days, countless larvae could be seen on strands of silk streaming out from trees. Many of the insects were carried away by air currents. The surface of Big Canon Lake, a body of water close to four square miles in area, was covered with larvae, at an estimated density of 100 larvae per square foot of surface. At other times, however, emergence may be gradual or there may be two distinct periods of abundant emergence. Furthermore, the time of abundant larval emergence through six years has varied by as much as four weeks. Because of such differences, prevailing spring temperatures were examined to determine what relationship might exist between temperature and the time and character of emergence. This paper points out a relationship between emergence and April and May temperatures, and an apparent temperature threshold for emergence.

Methods

In the course of ecological studies in 1947 and 1948, material was collected throughout the development of the insect from nine different plots in the vicinity of the Cedar Lake Field Station. At each visit to each plot, approximately twenty 18-inch branches were obtained from a number of balsam fir (*Abies balsamea* (L) Mill.) trees. The numbers of buds and insects were counted on each branch, and the insects were classified by instar. During the period 1949-1952, material was collected twice weekly from one of the plots previously used, Branches were obtained by means of pole clippers from trees averaging 30 feet in height and growing away from the immediate influence of taller trees. Enough branches were taken each time to obtain a minimum of 100 insects. The branches were examined in the same manner as in previous years. From these data, the progressive development of the insects from the time of spring emergence to the time of adult emergence was determined for each of the six years.

Since meteorological records were taken only from May to October at the Field Station, and since April temperatures seemed to exert considerable influence on larval emergence, temperature records from Sioux Lookout, a Canadian Department of Transport meteorological station 55 miles east of Cedar Lake, were used. Daily maximum temperatures at Sioux Lookout varied little from those at Cedar Lake during the summer, and average monthly temperatures were almost identical.

Results and Discussion

Table I shows the monthly mean temperatures and their deviations from the 1914-1950 averages for April and May, together with the dates of abundant emergence of spruce budworm larvae for the years 1947-1952. The time of larval emergence reflects the April temperatures for each of the years. April temperature in 1949 and 1952, when emergence was early, show a deviation of +6.6°F. and +8.5°F. respectively, whereas in 1947 and 1950, when emergence was late, the deviations were −4.2°F. and −7.9°F. The years 1948 and 1951

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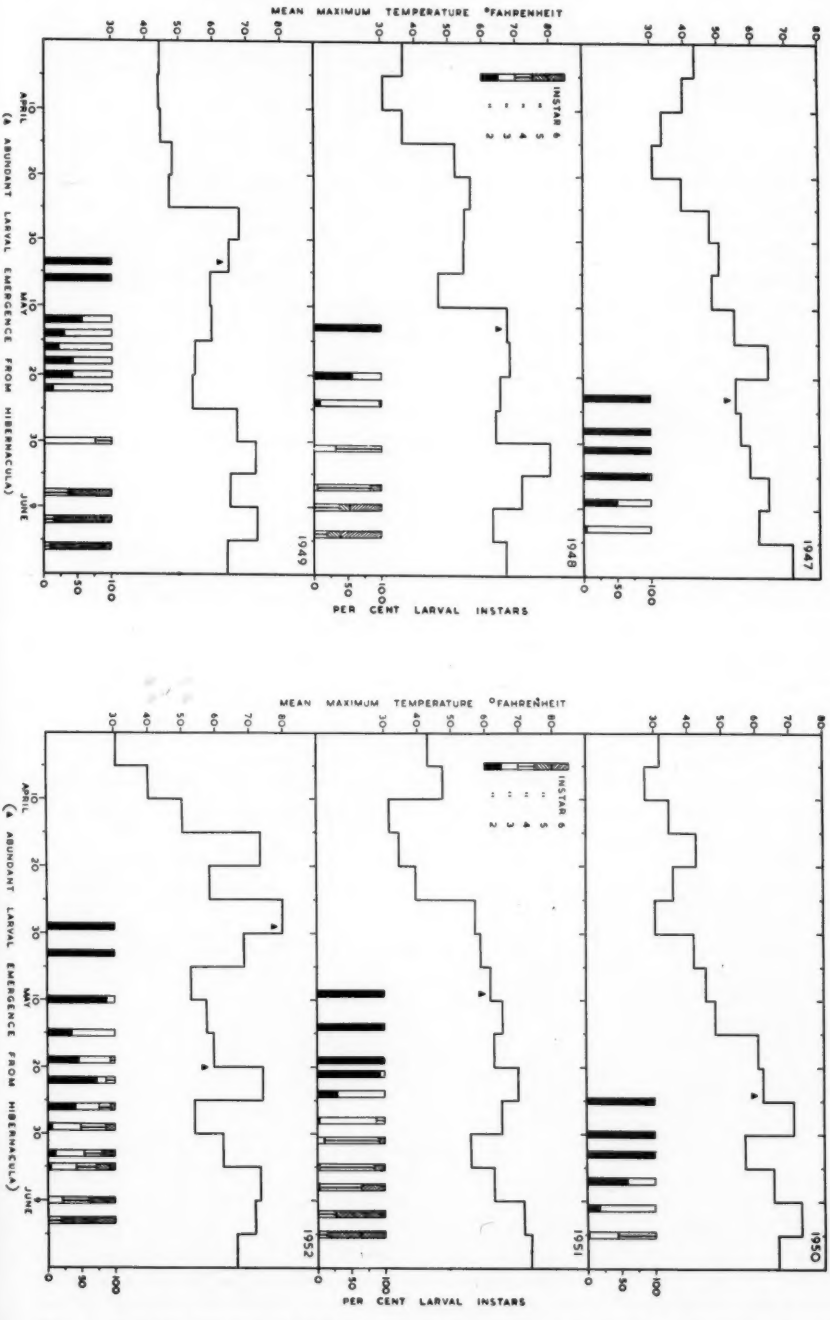

Fig. 1. Five-day averages of daily maximum temperature, time of spruce budworm larval emergence, and early larval development, 1947-1952.

TABLE I

Monthly Mean Temperatures and their Deviation from the Average Temperatures (1914–1950) for April and May, and the Dates of Spruce Budworm Emergence for 1947–1952

Year	April		May		Date of Emergence
	Mean Temp. °F.	Deviation from average	Mean Temp. °F.	Deviation from Average	
1947	28.8	− 4.2	43.2	− 4.6	May 23
1948	34.4	+ 1.4	49.6	+ 1.8	May 12
1949	39.6	+ 6.6	49.0	+ 1.2	May 3
1950	25.1	− 7.9	44.6	− 3.2	May 24
1951	33.0	0.0	52.2	+ 4.4	May 9
1952	41.5	+ 8.5	44.5	− 3.3	April 29 and May 20

approached the normal temperature for April, and the time of spruce budworm emergence for these years probably came close to an average date. The time of spruce budworm emergence also reflects the average May temperatures, for these complement the effects of the April temperatures.

Fig. 1 shows the time of abundant spruce budworm emergence, the percentage of the larvae in each instar, and the average maximum temperatures for five-day periods from April to June, for the years 1947-1952. In all six years, abundant larval emergence took place after temperatures had risen to, or above, 60°F. This was as early as April 29 in 1952 and as late as May 24 in 1950. In 1948 and 1951, abundant emergence took place within the first five-day period with maximum temperatures over 60°F; in 1947, 1949, 1950 and 1952, emergence took place several days after temperatures had reached 60°F. If preceding temperatures had been low and the rise to 60°F. was sudden, emergence was delayed; if preceding temperatures had been high and the rise to 60°F. was gradual, emergence followed almost immediately.

In 1947, 1948, 1950, and 1951, the percentages of the population in each instar followed normal curves. The length of time spent in the various instars was partly dependent on temperature. For example, in 1947 close to 100 per cent of the population was still in the second instar 12 days after the time of abundant emergence. During that time, maximum temperatures averaged less than 60°F. In 1948, seven days after the time of abundant emergence, almost half the population had reached the third instar; in that period average maximum temperatures had been over 65°F.

In 1949, and especially in 1952, collections from the field indicated a sudden rise in the relative numbers of second-instar larvae some time after initial abundant emergence. In 1949, although the early spring temperatures were not as high as in 1952, they were higher than average, and the larvae began to emerge on May 3. The sample collections for May 18 and 20, 1949, showed a slight increase in the relative number of second-instar larvae over the previous collections, indicating that a second emergence might have occurred just before the 18th. This increase in the percentage of second-instar larvae, did not however, coincide with any noticeable increase in total population. The maximum daily temperatures

on May 16 and 20 were 71 and 61 degrees respectively. In this year the second period of emergence indicated by the results could possibly be attributed to sampling error.

On the other hand, in 1952, definite evidence was obtained that two peaks of emergence occurred as much as three weeks apart. In 1952, abundant emergence took place on April 29, and for the following two weeks development was gradual. By May 15, only 35 percent of the population remained in the second instar. However, at the time of the May 19 collection approximately half the population were found to be in the second instar. Three days later about 75 per cent of the population were in the second instar. At the same time, 15 per cent of the population had reached the fourth instar. In other years, there were practically no insects in the second instar when fourth-instar larvae first appeared. Furthermore, the recurrence of large numbers of second-instar larvae coincided with a marked increase in population density. Table II shows the number of insects per 100 buds in 1951 and 1952. Samples on and after May 22 in 1952 contained larvae from the two periods of emergence, with approximately one third of the population from the first and the remainder from the second.

TABLE II

Number of insects per hundred buds of balsam fir in early samples.

Date	1951	Date	1952
14/5	21.7	10/5	7.5
19/5	33.7	15/5	7.4
21/5	24.3	19/5	9.3
24/5	24.1	22/5	22.7
28/5	43.6	26/5	26.3
31/5	31.8	29/5	26.7
4/6	32.4	2/6	23.9
7/6	35.8	4/6	27.6

This situation was attributable to the unusual weather conditions that prevailed in 1952. There were several days of record high temperatures in late April, providing an average maximum temperature for the period April 25-30 of almost 80°F. This warm period caused some spruce budworm larvae to emerge. It was followed by two weeks of cooler, more seasonable weather. On May 20, temperatures rose again and the recorded average maximum for May 20-25 was 74°F. It was at this time that the second peak of emergence occurred.

Records of spruce budworm emergence at Black Sturgeon Lake, about 200 miles east of Cedar Lake, were examined along with temperature records. A similar relationship between temperature and the time of emergence of spruce budworm was obtained for five years, 1946-1950.

Although the time of spruce budworm emergence in the spring varies considerably from year to year, it is felt that now it will be possible to predict more accurately the time of emergence in northwestern Ontario and, possibly, elsewhere.

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A Simple Method of Rearing *Hylemya brassicae* (Bouché) (Diptera: Anthomyiidae)[1]

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Investigations at Fredericton requiring specific instars of the cabbage maggot, *Hylemya brassicae* (Bouché), led to studies of laboratory methods for rearing this insect. Previous attempts to rear *H. brassicae* had proved unsuccessful since the species does not reproduce readily under artificial conditions. Slingerland (1894) was unable to obtain eggs of this species, though his cages contained hundreds of adults. Washburn (1906) reported that adults that had matured in the field would oviposit in cages. Schoene (1916) used adults that had emerged in the laboratory as well as some fresh-looking individuals captured at large. These were supplied with water and some cruciferous plants, as well as banana, sugar, water, and blossoms of weeds common in his community. Adults fed readily upon the sweetened mixture and decaying banana, and lived four to eight weeks. One female was dissected and found to contain 13 full-sized eggs, but no reference to oviposition was made.

A colony of *H. brassicae* has been maintained at the Fredericton laboratory for 17 months.

Adults were kept in the greenhouse in a wire-screen (breeding) cage 48 by 24 by 29 inches, with two doors, 12 by 12 inches. The floor of the cage, which was supported by wooden slats, was kept at nine inches above the greenhouse bench. The space between the greenhouse bench and the cage was filled to a depth of six inches with damp sphagnum moss to maintain a high humidity. Flies in the cage were supplied with water (Smith, 1952) to which three cubes of sugar had been added.

Two tablespoons of the following diet were supplied daily in a clean pie tin: one cup of corn meal was stirred into three cups of boiling water; when the mash had thickened, one cup of milk (unsweetened), half a cup of molasses, two tablespoons of wheat germ oil, and two teaspoons of liver extract were mixed with the mash; when the mash had cooled, 150 milliliters of extracted turnip juice were stirred into it. This diet gave good results, although all the components may not have been necessary.

Small boxes six by six by three inches were filled with fine, moist sand to a depth of two inches. In each box a small turnip from which the root hairs and the tap root had been removed was placed on the sand, and the box was placed in the cage. Oviposition readily took place in the box, the eggs being deposited in the sand around the turnip. Each box was left in the cage for two to three days, after which it was removed to the greenhouse bench. Boxes removed from the cage contained 200-300 eggs and were watered lightly but were otherwise undisturbed. The eggs hatched three to five days after oviposition and the young larvae found their way to the turnip, in which they fed and tunnelled. It required 20 to 30 days for the larvae to become full-grown. They then left the turnip, burrowed into the sand, and pupated.

It was 14 to 20 days before the first adult emerged. When pupation was complete the boxes were either placed in the cage or held in storage. Pupae

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have been held in storage at 35°F. up to five months. When emergence was desired, the sand containing the pupae was moistened and the material placed in the cage. Adults began emerging the following day and continued to emerge for approximately 30 days. A small percentage have not emerged after this treatment.

A fluctuating temperature of 60° to 80°F. favoured emergence. Pupae held at a constant temperature of 60° for 60 days failed to emerge. However, when they were transferred to a fluctuating temperature they began to emerge almost immediately. At a relative humidity of 60 to 80 per cent and with approximately 16 hours of light per day, activity was maintained at a high level and both mating and oviposition occurred. Keeping the cages well stocked with adults (150-200) has proved beneficial for maximum oviposition. When numbers of adults were seen to be diminishing, additional stocks of viable pupae were placed in the cage. Examination of dead adults has shown a ratio of 1:1 for the sexes.

If first-instar larvae were desired for an experiment, slices of turnip in a petri dish were introduced into the cage and left overnight. This method would usually provide 50 to 75 eggs by morning. These were removed to glass cylinders by means of a camel's-hair brush and incubated by the plaster of paris technique described by Searles (1928).

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Damage to Sweet Clover Seed by the Sweetclover Weevil, *Sitona cylindricollis* Fahr. (Coleoptera: Curculionidae)[1]

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Numerous reports have been received from growers in Manitoba and Saskatchewan that the sweetclover weevil, *Sitona cylindricollis* Fahr., greatly reduces sweet clover seed yields by feeding on the seed or by causing it to drop. It is known that weevil populations are often very high in clover fields that are left for seed. To determine the amount of damage that might be caused to seed by the weevil, a number of tests were conducted in 1951 and 1952.

In the first series in 1951, weevils were placed in small screen sleeve cages over racemes of ripe and of green seeds on plants growing in the field; the racemes had been shorn of foliage and terminal buds. In the second series, two-foot-square screen cages, about four feet high, were placed over the whole plants with both ripe and green seed racemes, in the field. In 1952, the sleeve cages were used over foliated racemes of green and of ripe seeds in the field in one

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series; and screen-topped glass vials containing cut, defoliated racemes of ripe seeds alone, and of green seeds alone or with foliage cuttings were used in the laboratory in another series.

Newly emerged adults of the summer brood were collected from infested fields for use in the tests. In 1951, in triplicate tests, 10, 20, and 40 weevils were used per cage in the sleeve cages; in a single test, 400, 800, and 1600 weevils were used per cage in the large cages over whole plants. In 1952, in five tests, 10 weevils each were placed in the vials; in three tests, 10 weevils each were used in the sleeve cages. Cages containing no weevils were used as checks in all cases except in that with large cages over whole plants, as the weevil population was extremely low in the experimental field.

In 1951, in the sleeve cages in the field a number of ripe seeds were detached from the racemes. This was the result of wind damage rather than of weevil activity since seeds were also detached in cages containing no weevils; further, the average number of seeds still on racemes in the shelter of the large, weevil-infested cages (15.4) was higher than that on racemes in the open, weevil-free area (9.6). In 1952, no seeds were detached from racemes kept in vials in the laboratory despite the continuous crawling of weevils over the easily detached seeds.

When the green seeds were damaged, only the seed itself was chewed on, not the seed pedicle. As shown in Table I, the weevils fed only on green seed; ripe seed was left untouched. When the green foliage was placed with the green seeds, the amount of seed damage dropped considerably; this suggested that foliage was a preferred food.

TABLE I

Damage to Sweet Clover Seeds by *Sitona cylindricollis*, Brandon, Man., 1951–1952

Year	Type of cage	Total no. of weevils	Days' exposure	Seeds damaged		
				Number examined[1]	Number damaged	Per cent damaged
	GREEN SEEDS ALONE					
1951	Sleeve cages	210	13–15	1230	465	37.8
1952	Vials	50	10	1000	199	19.9
	GREEN SEEDS WITH FOLIAGE					
1951	Large cages	2800	12–19	2640	118	4.8
1952	Sleeve cages	30	5	645	26	4.0
1952	Vials	50	10	1000	39	3.9
	RIPE SEEDS ALONE					
1951	Sleeve cages	210	15–36	1317	0	0.0
1952	Vials	50	10	1000	0	0.0
	RIPE SEEDS WITH FOLIAGE					
1952	Sleeve cages	30	5	444	0	0.0

1 Only a portion of the seeds in the large cages were examined; in other tests all the seeds were examined.

Gratitude is expressed to the officers of the Canada Experimental Farm, Brandon, for providing space for the tests.

(Received January 12, 1954)

Progress in the Use of the Precipitin Test in Entomological Studies [1,2]

By A. E. R. Downe[3] and A. S. West[4]

The possible uses of the serological precipitin test for investigating certain entomological problems have been reported previously by West (6). It was suggested that the precipitin test offered a new tool which together with such tools as the electron microscope, paper chromatography and radioisotopes would contribute materially to future advancement in entomology. It is evident to everyone that progress in many branches of entomology is being made currently by the use of new and improved procedures.

The suggested uses of serology were in relation to problems in systematics, identification of blood meals of biting flies and for studies of insect predator-prey relationships. It is the purpose of this paper to report the progress made along these lines in our laboratory. Telfer and Williams (5) have recently adapted the serum-agar modification of the precipitin test to a study of insect metamorphosis.

To date no systematic studies as such have been undertaken. However, a number of insect antigens have been prepared and stored for future use. The possibilities of distinguishing closely related insects by serological means have been demonstrated in conjunction with predator studies.

Initial serological studies in our laboratory were concerned with the identification of the blood meals of biting flies as a part of the Northern Biting Fly Research Program. After two summers of intensive searching at Churchill, Manitoba, it became apparent that very few engorged mosquitoes which had not in all probability fed on man or dog could be collected. Coupled with other studies these findings may suggest that some of the mosquito species in the Churchill area are normally plant feeders which may attack man or other hosts. During two summers 26 engorged mosquitoes were collected and smeared on filter paper. Specific identification was not possible in every instance but most of the engorged individuals were *Aedes hexodontus* Dyar.

After being stored two and three years these smears were extracted and precipitin tests were performed with human, dog and avian (chicken) antisera. Chicken antiserum produced in rabbits is non-specific and will detect all avian antigens (1). Although inhabited and travelled areas were avoided in collecting, eleven smears reacted with dog antiserum and 10 with human antiserum. One smear gave positive reactions with both dog and human antisera indicating that the mosquito concerned had fed on two hosts. Two smears gave positive precipitin tests with avian antiserum and two did not react with any of the antisera used. These results suggest that *A. hexodontus* feeds occasionally on birds and probably on mammalian hosts other than man and dog.

The validity of these interpretations is based on previous studies of factors influencing the performance of precipitin tests in the identification of blood meals (2) and studies on the rate of digestion of blood by mosquitoes (7). In the latter study it was shown that the host blood could be detected in the mosquito for as long as eight days after engorgement, depending on temperatures prevailing during the period of digestion.

1These studies have been aided by grants from the Division of Entomology, Science Service, Canada Department of Agriculture, the Research Council of Ontario and the Committee on Scientific Research, Queen's University.

2Paper presented at the 90th Annual Meetings of the Entomological Society of Ontario, London, Ont., November, 1953.

3Research Assistant and 4Professor of Zoology, Department of Biology, Queen's University.

The results of fundamental studies on the use of the precipitin test for identifying blood meals have made possible plans to investigate the feeding habits of biting flies in the more populated parts of Canada. These and other studies are being planned in cooperation with the Veterinary and Medical Entomology Unit, Canada Department of Agriculture, without whose support much of the work of the past several years could not have been undertaken.

During the past two years emphasis has been placed on the development of the use of the precipitin test for determining the feeding habits of predatory insects. Initial studies have been reported by Hall (3). The precipitin test offers a means of finding out what proportion of a population of a predatory species has fed on a particular host. The advantages of the technique are that no time-consuming field observations are necessary. Rather the predators are collected, smeared on filter paper and then subjected to serological examination at some convenient future time. No marking of the host is necessary as when radioisotopes are used.

A brief outline of the procedures involved is presented for the benefit of entomologists who may wish to use this technique in the future.

In order to determine to what extent a predator feeds on a particular host it is necessary to produce a host antiserum. This requires an adequate field collection of the host. In our laboratory a volume of host material approximately equivalent to the bulk of 1,000 full-grown codling moth larvae has been set as a standard. Smaller amounts may be adequate when reasonable success attends attempts to produce satisfactory antisera. Host material should reach the laboratory in a living state.

In the laboratory the host material is crushed, extracted with an equal volume of physiological saline and sterile filtered. The resulting antigen solution is injected into rabbits or chickens to stimulate the production of antibodies. When precipitin tests on trial bleedings have established that a satisfactory antiserum has been produced the animal or bird is bled and the antiserum stored in a frozen state until required.

Field collections of predators are naturally required. The predators are simply smeared on a piece of filter paper. Each smear after being allowed to dry is placed in an envelope and the pertinent data recorded. Where possible it is desirable to have as controls a few smears of predators which are known to have fed on the host concerned. Pinned or preserved specimens of predators should be retained for identification purposes. The preparation of smears requires very little time. The whole serological technique is admirably adapted to conditions faced by most field workers who are pressed for time during the active season. Seasonal time is not a factor in the serology laboratory since smears can be stored at least two years before being assessed.

In the laboratory smears are cut from the filter paper and extracted with physiological saline. The extract is tested against an appropriate antiserum using the interfacial "ring" test. The formation of a ring of precipitate between the extract (antigen) and the antiserum constitutes a positive reaction and indicates that the predator has fed on the host concerned. A number of improvements in techniques of precipitin testing as applied to predator studies have been made but the technique has not been reduced to a routine procedure. Detailed procedures will be described in another paper.

Results of studies of the association of a reduviid predator (*Zelus exsanguis* Stahl) and the forest tent caterpillar (*Malacosoma disstria* Hbn.) have been reported by Hall et al (4). In "known-feeding" tests it was shown that tent caterpillar material (antigen) could be detected in the gut of the predator smeared on filter paper as long as seven days after feeding when the predator

was held at room temperature in a field laboratory and for at least four days when the predator was held at a constant temperature of 25°C. before being smeared. Additional studies during the summer of 1953 showed that predators held at room temperature would feed on a tent caterpillar at least every fifth day and usually more frequently. It is evident that serological assessment of field collected predators will give an accurate evaluation of the feeding habits of the predator as concerns the forest tent caterpillar. During the summer of 1951 the caterpillar was present in epizootic numbers in the vicinity of the Queen's University Biological Station where these studies were conducted. Approximately 50 per cent of 118 field-collected individuals of Z. *exsanguis* gave positive precipitin tests with anti-forest tent caterpillar larva serum.

During the summer of 1953 the forest tent caterpillar was much less abundant. A series of 70 smears of field-collected Z. *exsanguis* adults was prepared. Field observations suggested that the predator fed less commonly when the host was less abundant. Precipitin test studies substantantiated this impression.. Twenty-six per cent of the series of 70 smears gave positive precipitin reactions. From the results of these studies it is concluded that Z. *exsanguis* is only an occasional feeder on the forest tent caterpillar at low population levels, but feeds more regularly when the caterpillars are abundant. The serological evidence suggests that predation on the tent caterpillar is a matter of chance encounter. Z. *exsanguis* cannot be regarded as an important natural control agent.

Another application of this serological technique has been made in connection with a study of predators of the codling moth (*Carpocapsa pomonella* L.) in Nova Scotia apple orchards. A number of suspected predators have been shown to feed on the eggs of the codling moth or eggs of a close relative. In these studies the sensitivity of the precipitin reaction has been emphasized in the demonstration that codling moth egg material can be detected in insects as small as predatory thrips, using a high-titred anti-codling moth pupa serum (4).

Currently in our laboratory investigations of known or suspected predators of larval stages of mosquitoes in the vicinity of Churchill, Manitoba, are being conducted. This study has been made possible through the cooperation of the Belleville Laboratory of Entomology. In all previous studies (3,4) only high-titred (1:2500 or greater) anti-sera have been used. An important advance has been made in the current studies which show that low-titred (1:100) but avid antisera will detect mosquito antigen in predator smears. Since one of the greatest difficulties in the past has been in producing high-titred anti-host insect sera this discovery has removed a major block to the extensive application of the precipitin test to predator studies.

The current studies have shown that whereas large species of dytiscid adults regularly feed on mosquito larvae adults of smaller species do not. Gerrid adults are consistent predators on mosquito larvae. In the early part of the season trichopteran larvae seldom prey on mosquito larvae. During the period when mosquito larvae are completing their development larvae of the same species of trichoptera regularly feed on mosquito larvae. The findings on predation by Trichoptera are in agreement with those of Baldwin[1] who has used radioisotopes to study predation on immature mosquitoes. Several of a series of smears of a snail gave positive precipitin tests and predation by this snail was observed in the field. Specimens of all predators have been retained for specific identification.

Discusson

The advantages of the precipitin test have been stated. There are also certain limitations particularly with respect to predator studies. The collection of a

[1]Baldwin, W. F. Laboratory of Entomology, Belleville, Ontario. Personal Communication.

sufficient volume of host material is not always easy. In any extensive program it would be logical to collect host material as it was readily available and stockpile for future use.

In serological studies of any type the rabbit or other antibody producer has always been an unpredictable variable. At times it is necessary to inject several animals in order to secure a satisfactory antiserum. The experiences in our laboratory suggest that the production of satisfactory anti-insect sera is not now a major stumbling block. Continued fundamental studies on insect antigens are, however, warranted.

The precipitin test is not completely specific. An anti-serum may react not only with the antigen which was used in its production but also with closely related antigens. This problem of cross-reactions may present difficulties or be of value depending on the circumstances of a particular problem.

During initial studies of mosquito predators the supply of anti-mosquito serum was exhausted. An anti-chironomid serum was used to continue testing of smears of suspected predators. Since chironomids were not a factor in the field the cross-reaction occurring because of the relationship of chironomids and mosquitoes was put to good use.

On the other hand in the Nova Scotia codling moth predator studies it has been found that a codling moth antiserum reacts with antigens of a variety of Tortricids and Olethreutids. Thus a smear giving a positive reaction indicates that the predator may have fed on a stage of the codling moth or a stage of a close relative. Cross-reactions can be reduced or eliminated by dilution and absorption of antisera.

The projected investigation of a number of fundamental aspects of the application of the precipitin test to entomological problems will undoubtedly lead to more refined techniques and more sensitive tests. However, progress during the past three years has shown that a tool which has been used extensively for a number of years in the identification of blood meals of biting flies and to a limited extent in investigations of problems in systematics can now be applied to another aspect of entomological research, namely the study of insect predator-prey relationships. Since evaluation of predator-prey relationships has been difficult in the past it is hoped that this new technique will be of material aid in the future.

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The Instars of a Maggot *(Pegohylemyia)* Inhabiting White Spruce Cones[1]

By HOWARD A. TRIPP

Introduction

Maggots of *Pegohylemyia sp.* have been found inhabiting the cones of white spruce, *Picea glauca* (Moench.) Voss, in southern Ontario. The species was identified from a single male specimen as probably *Pegohylemyia anthracina* Czerny by the Swedish authority Dr. O. Ringdahl. Difficulty in rearing the maggots to the adult stage has delayed confirmation of this identification but it is expected that a good series of adults will be available shortly. In this paper, however, the emphasis is placed on the instars with an outline of the life cycle. It is shown that the second- and third-instar larvae are free-living, but the first-instar larvae moult to the second within the egg chorion.

Methods

Eggs and larvae were preserved in 70 per cent alcohol. To study the buccopharyngeal skeleton, third- and large second-instar larvae were heated slowly in a 10 per cent caustic solution in a water bath for one-half to two hours depending on the size of the larvae. The specimens were then washed in water and the gut contents manipulated through a hole in the integument. After passing through graded alcohols they were mounted in Euparal. This treatment was too harsh for eggs and newly-hatched larvae. These specimens were placed in glacial acetic acid, then in a mixture of two parts acetic acid and one part clove-oil and finally in a mixture of equal parts acetic acid and clove-oil (2). They were allowed to remain in each reagent for at least 20 minutes. They were often held for several days in the third liquid before being mounted in Euparal.

Life Cycle

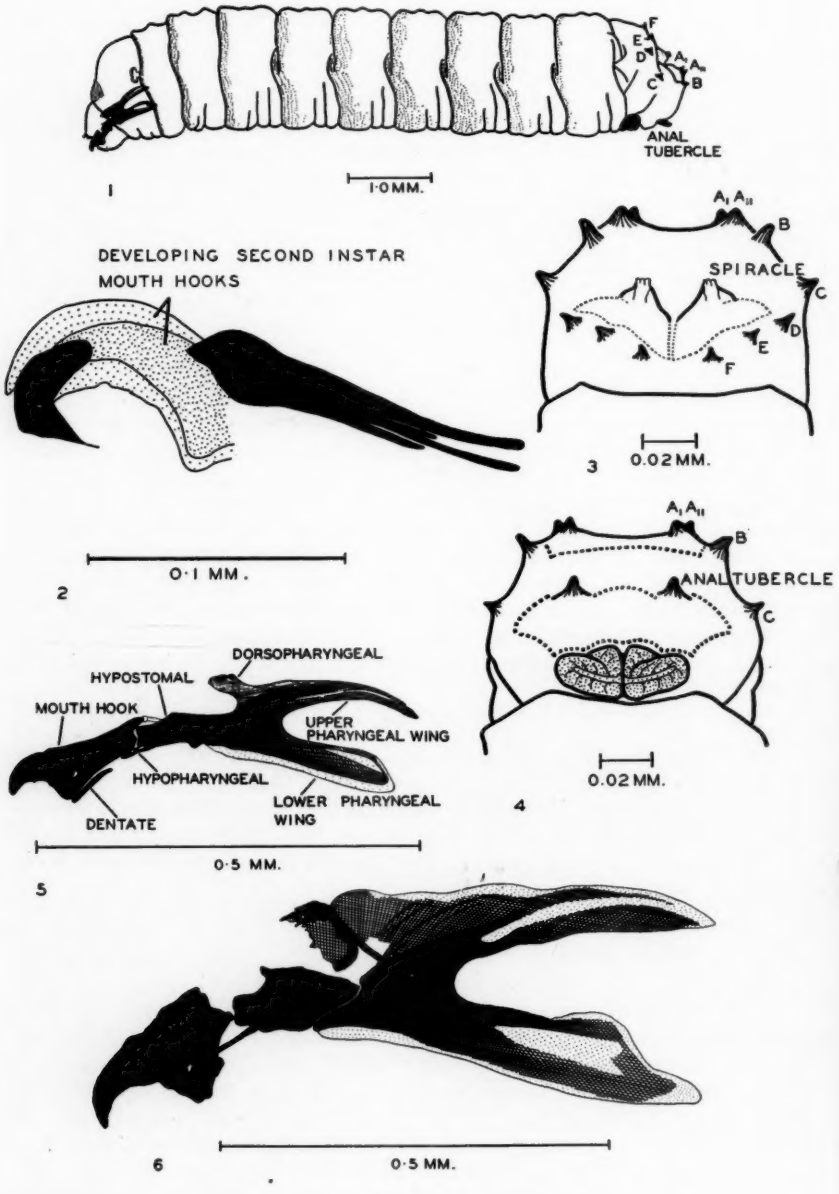
Eggs are deposited between the cone scales about mid May, usually during the pollination period when the scales are open. They hatch in four to five days. The maggots tunnel spirally about the rachis, eating through the bases of the scales and destroying the seeds (Fig. 7). In June, after about three weeks' feeding, they tunnel their way out of the cone and drop to the ground. They overwinter as pupae and emerge in early May.

Instars

The maggots moult once before forming puparia, resulting in only two free-living larval instars. As most Anthomyid species have normally three instars (1) it would appear that an instar is missing in this species. The structure of the two free-living forms indicates that they are second- and third-instar larvae. Newly-hatched larvae are amphipneustic whereas typical first-instar anthomyid larvae are metapneustic. The two anterior spiracles each possess 15 to 16 lobes (Fig. 15); the two posterior each have two openings (Fig. 12). In addition, the structure of the buccopharyngeal skeleton is typical of a second-instar larva (Fig. 5). Newly-hatched larvae have large paired mouth hooks, paired dentates, large hypostomal sclerites, hypopharyngeal sclerites, and split upper pharyngeal wings which are all characteristic of second-instar larvae.

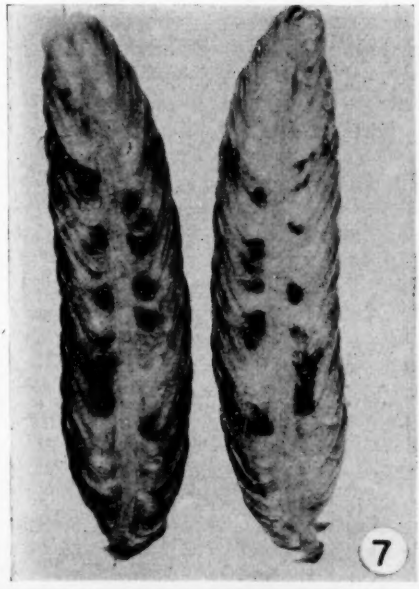
After the first moult the larva is amphipneustic with similar anterior spiracles (Fig. 16) but with three openings in each of the posterior spiracles (Figs. 13 and

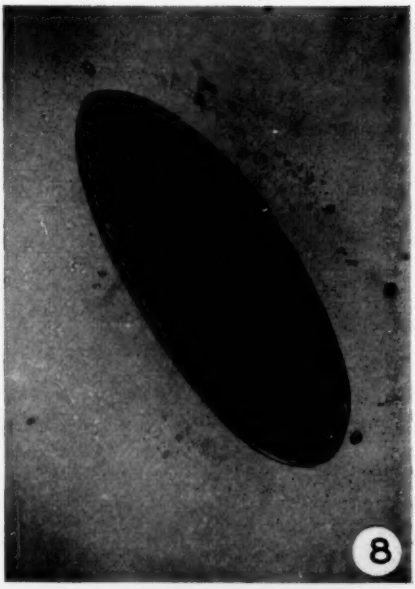
1Contribution No. 123, Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada.

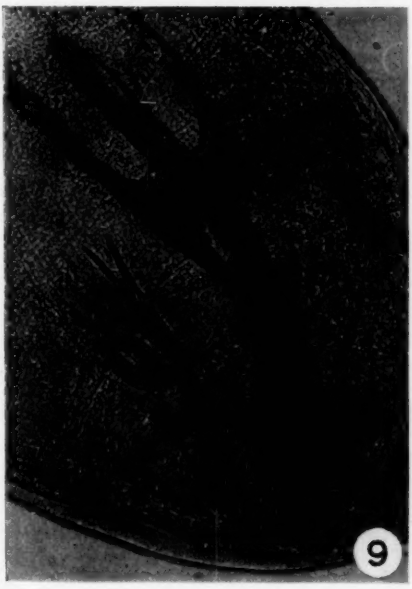


Figs. 1 to 6

1. Third-instar larva. 2. First-instar mouth parts showing formation of second-instar mouth hooks. 3. Dorsal view of posterior segment of third-instar larva. 4. Ventral view of posterior segment of third-instar larva. 5. Second-instar buccopharyngeal skeleton. 6. Third-instar buccopharyngeal skeleton.

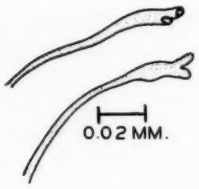






Figs. 7 to 10

7. Injury to a white spruce cone by a single maggot. 8. Egg showing fully developed second-instar mouth parts. 9. Anterior portion of egg showing first- and second-instar structures (see also Fig. 17). 10. First-instar larva exuviae.



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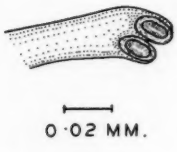

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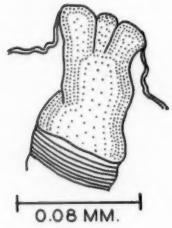

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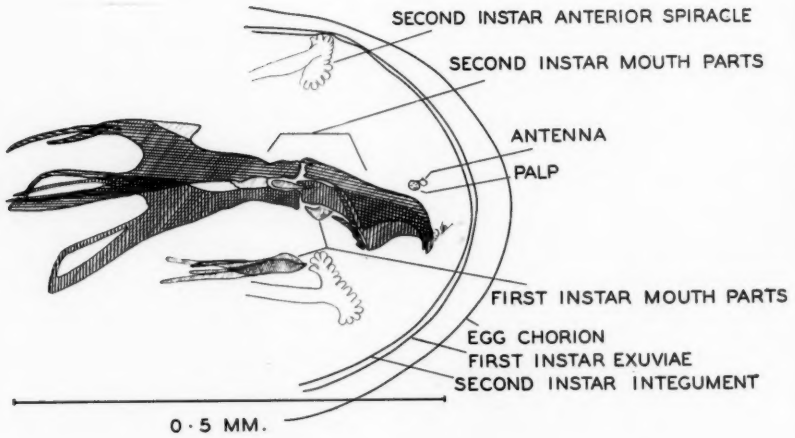

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Figs. 11 to 17

11. First-instar posterior spiracles. 12. Second-instar posterior spiracle. 13. Third-instar posterior spiracle showing spiracular openings. 14. Third-instar posterior spiracle, lateral view. 15. Second-instar anterior spiracle. 16. Third-instar anterior spiracle. 17. Diagrammatic illustration of anterior portion of egg showing first- and second-instar structures (See also Fig. 9).

14). The buccopharyngeal skeleton is much larger and has a more complicated structure (Fig. 6). Pharyngeal skeletons dissected from puparia are similar to those taken from freshly moulted larvae. The tubercles on the posterior segment (Figs. 3 and 4) are similar to those on the second instar but unlike the previous instar this larva posseses irregular rows of small spines along the anterior borders of segments 3 to 11 (Fig. 1). It appears that this larva is in the third instar.

Evidence of the first -instar larva was found within the egg (Fig. 8). Several eggs in various stages of development were examined. Eggs early in development showed the formation of the first-instar pharyngeal skeleton but in all specimens examined the first-instar skeleton was partly hidden by the developing second-instar hooks which formed over it (Fig. 2). In advanced stages of development the second-instar skeleton, being comparatively gross, often obscured the lightly sclerotized first-instar skeleton (Figs. 9 and 17).

Dissection of two nearly-mature eggs showed the exuviae of the first-instar larva overlying the second-instar larva and adhering closely to the inside of the chorion. The exuviae consist of a thin transparent membrane and the mouth parts of the first-instar larva (Fig. 10). Careful examination under high magnification revealed the presence of posterior spiracles (Fig. 11), antennae and palps of the first-instar larva (Fig. 10).

The phenomenon of newly-hatched larvae being in the second stage is not uncommon. R.C.M. Thomson has encountered several such cases in his study of the Anthomyidae (3). In fact, he has records of four species hatching directly into the third instar but in only one did he find a suggestion of a suppressed previous instar in the egg. It is quite likely that in many species or even individuals of the same species, the previous instar cannot be detected by ordinary methods.

Summary

It is clearly shown that this species has only two free-living larval instars. The newly-hatched larva is morphologically similar to second-instar larvae of other anthomyids whereas the last instar is typically a third. The first-instar larva develops within the egg chorion as shown by the presence of a somewhat suppressed first-instar buccopharyngeal skeleton within the egg. The presence of the first-instar exuviae clearly indicates a moult before hatching.

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Note on *Myzus certus* (Walker), an Aphid New to North America (Homoptera: Aphidae)

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On August 14, 1952, aphids were collected from common pansy, *Viola tricolor* L., at Fredericton, N.B. These were identified by the author as specimens of *Myzus persicae* (Sulzer). The infested pansy plant was placed in the greenhouse and in November sexuales appeared and oviposition occurred. Since *M. persicae* colonizes on potato readily, some of the aphids were placed on it to check on the identity of the species. Also, since *M. persicae* was not known to oviposit on pansy, mounted specimens were forwarded to D. Hille Ris Lambers, Bennekom, Holland, for examination. According to him (in litt.) two species were present, there being winged viviparous females of *M. persicae* and winged viviparous and wingless oviparous females of *Myzus certus* (Walker).

Hille Ris Lambers stated that the aphids that were transferred to potato from pansy in 1952 must have been specimens of *M. persicae*, since *M. certus* lives on *Viola tricolor* exclusively. However, in 1953, specimens of *M. certus* were collected from *Viola tricolor* in the same locality as in 1952 and when placed on excised potato leaves and young potato plants were maintained through several generations. This is the first record known to the author of the colonization of potato by *M. certus*.

This aphid is very similar to *M. persicae* and cannot be separated from the latter species by the key of Mason (1940). According to Hille Ris Lambers (in litt.) it differs in morphology from *M. persicae* mainly in the arrangement and number of hairs on the basal half of the terminal segment of the rostrum. *M. persicae* has one pair of marginal hairs and occasionally one or two additional hairs on the surface; *M. certus* has two pairs of marginal hairs and one to three surface hairs. *M. certus* causes a bunching of the growing shoots and an upward rolling of the young leaves of pansy, symptoms not produced by *M. persicae*.

Walker (1849) described the wingless viviparous female of *M. certus*. In the Fredericton laboratory collection there are winged and wingless viviparous females and wingless sexuales. This is the first known record of this species from North America.

References

Mason, P. W. 1940. A revision of the North American aphids of the genus *Myzus*. *United States Dept. Agr. Misc. Pub.* 371.

Walker, F. 1849. Descriptions of New British aphides. *Zoologist* 7, appendix, pp. xxx-xl.

(Received January 12, 1954)

Larval Description of *Acmaeops proteus* (Kby.) (Coleopt., Ceramb.)[1]

By L. M. Gardiner[2]

In studying populations of wood-boring beetles in dead trees or logs, it is usually the larval form with which the worker must deal. The various species have different habits and although they may be present in very large numbers, some may do no direct damage to the wood. For any estimate of the existing

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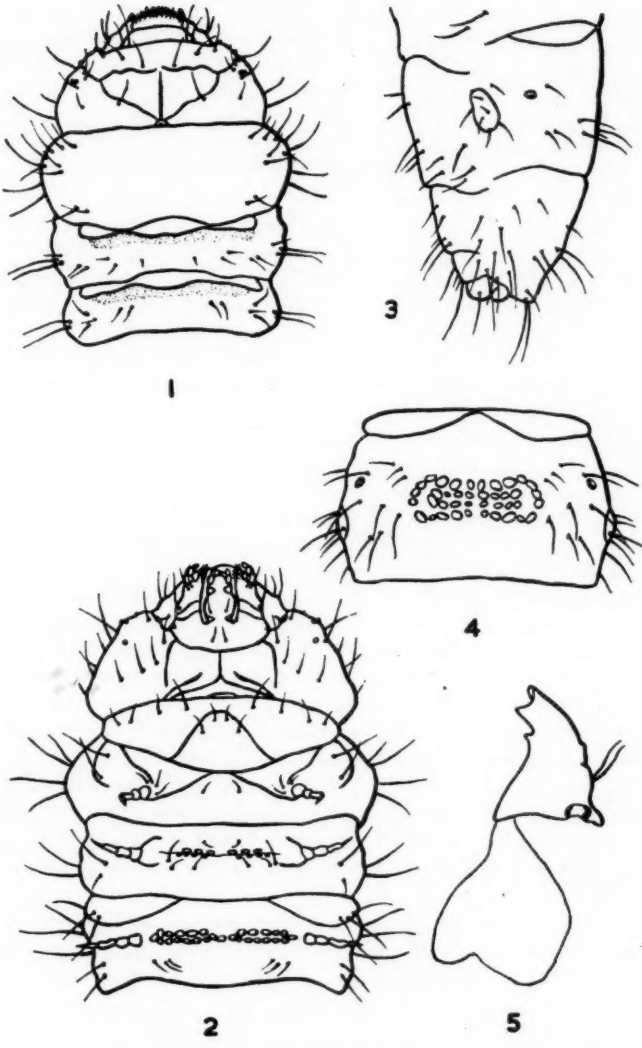
2Forest Insect Laboratory, Sault Ste. Marie, Ontario.

3Craighead, F.C. 1923. North American cerambycid larvae. Dom. Can. Dept. Agric. Bull. No. 27, n.s. (Tech.)



1. Head and thorax, dorsal aspect.
2. Head and thorax, ventral aspect.
3. Terminal segments, lateral aspect.
4. Abdominal tergum showing dorsal ampulla.
5. Right mandible.

damage-potential, larval identification is therefore an obvious prerequisite. During recent studies of wood-boring beetles in fire-killed pine in northern Ontario, the larva of *Acmaeops proteus* was by far the most common encountered, but its identity remained uncertain until a programme of rearing larvae from known adults was carried out. The apparent absence of a published larval

description of this, one of the most common cerambycids in our eastern coniferous forests, has prompted the preparation of this brief description.

In many respects, this larva is close to *Gaurotes cyanipennis* (Say) and *Evodinus monticola* (Rand.) as they are described by Craighead (1923).[3] However, it can be separated from the former, which attacks only hardwoods, on the bases of host trees and the number of ocelli, and from the latter by the absence of any spine on the ninth abdominal tergum. Employing Craighead's terminology, the description of *A. proteus* is as follows.

Form somewhat depressed, often compressed, sides subparallel; integument smooth, sparsely clothed with long, castaneous setae, especially on the lateral areas.

Head depressed, widest at the middle and tapering sharply anteroposteriorly; strongly sclerotized, bearing numerous, long setae; clypeus and labrum hyaline, the latter rounded anteriorly and ciliate; frons transversely divided; mandible slim, acute-tipped, more or less tridentate; antennae very small, retractile, ocelli five on each side. Anterior edge of hypostoma curved; tentorial pits prominent; gula not evident, a median suture; ventral mouth parts fleshy, terminal joints of palpi conical, last maxillary joint as long as second, lacinia digitate.

Prothorax twice as wide as long, weakly sclerotized; pronotum smooth, shining. Eusternum smooth, broadly rounded anteriorly, bearing four setae; mesonotum and metanotum asperate; mesosternum and metasternum tuberculate, tubercles only weakly developed in the former. Legs present, slender; tarsus a single attenuate claw.

Abdomen somewhat depressed, ambulatory ampullae on first seven segments; dorsal ampullae of four rows of small, shining tubercles; ventral ampullae of two rows; pleural tubercles oval, present on first eight segments; ninth tergum unarmed, bearing numerous, long setae. Spiracles suborbicular, borne on first eight segments.

Length 15.4 $\pm$ 1.5 mm., width of head capsule 2.4 $\pm$ .2 mm.; means and standard deviations of measurements made on 44 mature larvae.

In northern Ontario, *A. proteus* has been found breeding in dead white pine, red pine, jack pine, white spruce, black spruce, and balsam fir. The entire larval period is spent in feeding on the inner bark, which is converted to a mass of coarse frass. Pupation is believed to take place in the soil since no pupae have been found under bark.

(Received December 4, 1953)

Errata

On page 125, Vol. 86, the last paragraph on *Latalus hultus* n. sp. should read as follows:–

"Holotype, ♂ :–Birch River, Manitoba, August 13, 1930 (R. H. Handford). No. 6103 in the Canadian National Collection.

"Paratype, ♂ :–same data as holotype."

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